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Rationalization of Soil
and Water Research and Management

Moisture Management In Crop Production

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INTRODUCTION TO PROCEEDINGS

It is with great pleasure that we, the Planning Committee of the Fifth Annual Western Provinces Conference on the Rationalization of Soil and Water Research and Management, provide these proceedings of the Moisture Management in Crop Production Conference held in Calgary, November 18-20, 1986.

We wish to thank the speakers for their efforts in preparing and presenting their papers, the session chairmen for maintaining schedules, and participants who initiated good information exchange throughout the Conference, plus individuals and organizations who provided displays.

Finally, I want to thank the Conference Planning Committee, Adolph Goettel, Dick Hart, Russ Lewis, David Lloyd, Bob Nelson, David Neilson and Larry Welsh. Special thanks to Beverly Jones and Albert Yakiwchuk for their timely support on the registration desk, Serge Dupuis, for his computer assistance, Brenda Green for her graphics assistance, Alfreda Strzelec for her administrative support and secretarial staff, Mary Jane Horton and Jeannie Munroe for their support during the conference planning stages and assembly of proceedings.

John G. Calpas, Chairman
Conference Planning Committee

PLENARY SESSION I

PROBLEM IDENTIFICATION: LONG-TERM IMPLICATIONS OF DROUGHT

CHAIRMAN, W.J. DENT, ASSISTANT DEPUTY MINISTER,
FIELD SERVICES, ALBERTA AGRICULTURE

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ABSTRACT

Long-Term Climate Overview/Trends: Recurrence and Frequency of Drought

Dr. Timothy F. Ball

University of Winnipeg

The drought of the last two years has brought home once again the constant problem that prairie agriculture faces despite improvements in techniques, seeds, and machinery because of the vagaries of prairie weather. The extent and degree of climatic variation is gradually being accepted but even more gradually understood. Until the pioneering work of Lamb in England and Bryson in the United States there was very little study of the historic record and even today there is very little support for the reconstruction of past climates except on a generalized scale. These records are very important because without them climate models are limited to including only the range of climatic conditions of the instrumental period. In most parts of the world, including vast areas of Canada, this means either no record at all or at best a record of twenty to thirty years.

Historic records for central Canada are much more extensive than generally realized and provide a rich base for reconstruction of the conditions over the last 250 years. Preliminary examination of the precipitation patterns in these records suggest that the drought cycle established for the High Plains and Great Plains of the United States extend into Canada possibly including the boreal forest. A spectral analysis of precipitation data for York Factory, Manitoba shows a very distinct peak at 22 years indicating that droughts occured on that frequency for the period 1714 to 1800.

Other records show similar correlations with the drought cycles recorded in the United States and confirmed by tree ring data and the commentary of contemporary observers. One of the most famous of these was John Palliser who traversed the area in 1857 during a drought, it is not surprising that he reported that the southern region was generally unsuitable for agriculture.

These droughts have been clearly related to the 22 year, or Hale, sunspot cycle and occur near the sunspot minimum following a negative maximum. Similar cycles have been noted for droughts in parts of Africa, Europe making the correlation hard to ignore, however many questions remain to be answered.

Long-Term Climate Overview/Trends: Recurrence and Frequency of Droughts

Dr. Timothy Ball,
Associate Professor, University of Winnipeg

It is extremely difficult to define drought particularly with regard to its effect upon agriculture but that is the one that is most important to the human condition. The World Meteorological Organization produced a technical report in 1975 that provided many references to drought but grouped them into four general definition areas; rain; rainfall and mean temperature; soil moisture and crop parameters; and estimates of evapotranspiration and climatic indices. There is no doubt that the definition must result from a lack of precipitation over a certain period of time. Absolute values of the length of drought or the total amounts of precipitation are not very helpful in determining the effects on agriculture, particularly for a cereal grain such as Durum wheat which seems to thrive when conditions are relatively dry. Similarly, the timing of the precipitation in the growth cycle of the plant is of great importance to its effectiveness in producing a crop. From an agricultural point of view it is probably most useful to define a drought year according to the amount of precipitation available in critical periods of the plants growing cycle. It is also possible to define a drought from an economic perspective which would conjoin the social and economic devastation of the drought on a region.

Although it is difficult to define drought with modern instrumental records and extensive written observations it is even more difficult to establish what was a drought on the basis of absolute precipitation values in the historic record. Ironically it tends to be easier to determine what might have been a drought that would have been agriculturally damaging because of the effects on the natural vegetation. Observations in diaries coupled with tree ring data can provide a reasonable picture of the growing season.

Despite the problems it is necessary to work with the available material to determine the long term pattern of droughts in agricultural areas so that cycles can be determined and forecasting can allow for better preparation. Various researchers have studied the drought cycles of the High Plains region of the United States and the prairie region of Canada, a region that extends across the 49th parallel into the area that has been mistakenly described as the Palliser Triangle.

John Palliser defined the triangle as having Saskatoon at its apex, the U.S. boundary as its base stretching from Alberta to Manitoba and all within that area as being unsuitable for agriculture. Clearly this is an assessment that was hasty and based almost solely upon a brief observation of the soils, climate and drainage of the region during a drought year. Henry Youle Hind reported similar conditions in the Canadian sponsored expedition of 1857 -

1858 and provides an equally pessimistic assessment of the potential. Hind writes, " Whereas a proper appreciation and use of facts will convince the most sanguine, that the larger portion of this area, (the 400,000 square miles drained by the Saskatchewan) is, in its present state, unfit for the permanent habitation of man both on account of climate, soil, and absence of fuel." (Hind, 1860, p. 353). Both explorers were familiar with the literature and climate of the Great American desert, both believed that the long term prospects of the region were not good for agriculture. It is important to note that Hind does say in "in its present state" and qualifies this by saying that it would take human input to improve things, as had already occurred in the United States. He does remind the reader that soils are not enough, "...without giving due weight to the infrequency of rains, or the absence of the necessary humidity in the atmosphere, to produce a profitable vegetation." (Hind, 1860, p.354)

Douglass (1919, 1928, 1936) was one of the first to examine the relationship between sunspot cycles and the rainfall patterns of the High Plains region. His work was followed Borchert (1971), Marshall (1972), and Thompson (1973) while Roberts (1975) reviewed the evidence and strengthened the connection by carrying out a study of drought patterns for 1850 to 1960 in eastern Kansas. Mitchell et al. (1977) used tree ring data back to 1700 to demonstrate even more strongly the cyclical behaviour of droughts with a 22 year length coincident with the Hale sunspot cycle.

The Hale cycle was first identified by G. E. Hale in 1908 and reconfirmed by Hale and Nicholson in 1925. It is often referred to as the double sunspot cycle because it is the period of time in which the magnetic polarity of bipolar sunspots go through a complete cycle. The sunspot polarity in the 11 year or Schwabe cycle reverses at a minimum of sunspots while the 22 year cycle includes two successive 11 year cycles. The Schwabe events are defined as positive or negative with the former having outward polarity in the northern hemisphere of the sun and the latter having inward polarity in the southern hemisphere. At the end of this 'positive' cycle the polarities reverse and continue through the next approximately 11 years creating the 'negative' cycle. It must be stressed that the 11 and 22 year periods are only averages with the former varying from 8.5 to 14 years for the minima and 7.3 to 17 years for the maxima. The 22 year cycle is less variable and the associated drought cycles for the High plains region have a recurrent frequency of 20 to 22 years for the last approximately 150 years. It is this variability that probably accounts for the slight variation in the duration of the drought and thereby its socio-economic impact.

A major source of climatic information for Central Canada is the extensive record of the Hudson's Bay Company which includes daily weather commentaries and a great many meteorological journals. These have been studied in great detail by Ball (1982, 1983a, 1983b, 1984, 1985, and 1986), Wilson (1982, 1983a, and 1983b), Catchpole (1980), and Guiot (1986), provide a great deal of information about the climate of the region for the period from 1714 to the present. Unfortunately, there are no records of precipitation amounts until well into the Nineteenth century but there are detailed daily commentary on rainfall events from which it was possible to obtain frequency counts of the number of days of precipitation in a given month or week. The analysis was detailed enough to be able to identify several different types of rainfall, however it is the number of days without rain that are of interest in a drought study.

The most continuous period of daily record of precipitation events for the Hudson's Bay Company post at York Factory on southern Hudson Bay was from 1715 to 1802. A power spectrum was used to determine if there were any cycles in the number of months with no precipitation. A long term trend was in evidence that suggested that there was a cycle of approximately 300 years but this is difficult to confirm with an 87 year record. It is interesting to speculate that this relates to the 300 year sunspot cycle recognised by many researchers and generally linked to a similar temperature trend that historians, such as Arnold Toynbee believe relate to the rise an fall of empires.

There was also a very distinctive peak at 22 years and a lesser peak at 3.2 years. The 22 year peak is very distinctive because of its intensity but also because it apparently correlates with the previously mentioned sunspot and drought cycle. A similar spectral analysis was carried out for the same period for Churchill, Manitoba but only two peaks appeared, one at 7 years and the other at 3 years. This is not surprising because Churchill has a subarctic climate while York Factory is distinctly in the boreal forest zone.

The Daily Journals maintained by the employees of the Hudson's Bay Company at Posts along the shores of Hudson Bay have many general comments to weather but most of these are to the extreme cold, excessive snow, or cold wet summers. This is a reflection of those things that interfered with their daily routine rather than a reflection of the overall pattern therefore it is very significant when a comment is made about drought. The first direct reference occurs in 1772 when it is reported that, "Mosses catching fire. Summer a remarkable dry one". In 1773 this is confirmed and detailed in the comment "Indians general complaint that a great part of the country inland has been on fire the last summer it being so very a dry one to which the natives compute the scarcity of animals"

1790 appears to have been another dry year in the interior as there is a reference to the Churchill River being very low. The next indication of dry conditions occurs in the winter of 1809-1810 when the entry for the 19th of April notes, "Indians are coming to the Factory and complain much of the plains being bare of snow". The pattern of variability of precipitation from season to season from 1800 to 1810 is similar to that recorded in the journals for the settlement at Red River. Alexander Henry notes on the 28th of August, 1800 "The drought has been so great this season that there is no water in this little river" (The Plum River in southern Manitoba). The drought continues through to1805 except for the wet spring of 1803. These dry years were followed by the normal infestation of grasshoppers.

The years 1816 to 1819 were generally dry but this is probably due to the extensive volcanic activity reported by Lamb and others that resulted in severely cool weather conditions in the northern hemisphere. The dry conditions seem to be general because in 1821 William Ross reports that there was not enough water in the Seal River to allow a canoe to pass.

Good agricultural weather prevails in the prairie region through to 1837 when dry conditions are the general pattern until 1850 with the driest years being 1846 and 1847. Similar aridity is reported in the north. The journal entry for February 2nd 1844, reads "He adds that the reason why the proceeds of the fishery this season are not so large as those of last, was the dried up state of the shallow lakes where the fish are procured owing to the great drought of last summer".

In 1862 the drought and the grasshoppers return to the southern region and continue through to 1864 which seems to have been a very severe year with many days of over 100°F (37.7°C) temperatures. The situation was very severe with steamboat travel on the Red River impeded by low water levels which also prevented water powered flour mills from functioning. More serious was the fact that seed grain had to be imported from the United States in 1862 and again in 1865. Similar conditions of drought and heat were experienced in much of central and southern Europe with the decade of the 1860s being one of the hottest and driest on record.

The general pattern of 22 year cycles of drought continued to the end of the century with 1886, 1889 and 1894 having below long term average precipitation in southern Manitoba. Further west the situation was more severe as areas of Saskatchewan and Alberta experienced low precipitation levels. The interesting thing about the 1880s and 1890s is the extremely cold winters and generally cooler than normal temperatures in the summer months. This is a pattern that is related to the 90-100 year Gleissberg cycle of climatic conditions marked by extreme variability of all weather variables and wide ranges of temperature. Similar cold and variable conditons were reported in the European record with the period from 1880 to 1889 being the second coldest decade of the nineteenth century.

The twentieth century pattern of climate and droughts is well known and has been adequately covered by other papers at this conference. The statistical data for York Factory and the historic information presented here clearly shows that there is an approximately 22 year cycle of drought that extends across the prairie region and north into the boreal forest. The correlation of these droughts to those in the High Plains of the United States and with the Hale sunspot cycle suggests that future droughts can be predicted and appropriate action taken to alleviate the stress and offset the socio-economic damage.

The climate in the period from 1940 to 1975 has generally been ideal for grain production throughout the world and particularly in North America. During this period yields increased significantly and many people from all branches of the agricultural sector believed that technology, new seeds, and chemicals had allowed farmers to overcome much of the influence of climate. This is a very dangerous complacency that could be caught in a future change of climate that is currently beyond the 'official' record. As we move to the use of higher yielding grains that often have a narrower climatic tolerance it is essential to be able to have better forecasts.

We should not forget that although Palliser's triangle has been generally improperly defined, debated, and for many discredited, there are still many thousands of acres that never should have been broken to grain farming. Each time there is a drought we are reminded of this fact and yet the more we move away from the extreme period of the 1930s the more we forget the lessons learned so hard by so many. We forget that in the period from 1921 to 1926 there was a mass emigration from Alberta, mostly from the Palliser area, that resulted in over 10,000 abandoned farms by 1926.

It is apparent from the material presented in this paper that there is a direct link between sunspot cycles and drought sequences on the Prairies of Canada. The exact physical linkage is not yet understood although it is generally thought to be through the solar wind to the earth's magnetic field and thence through the jet stream, to the polar front and the fluctuations between zonal and meridional flow in the temperate latitudes. Regardless of the mechanics, the results can be devastating and have been more severe in past centuries and we ignore the pattern and the implications to our peril especially when we have some of the technology and skills necessary to anticipate and alleviate the problems.

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SOCIOECONOMIC IMPLICATIONS OF A PROLONGED AGRICULTURAL DROUGHT ON THE PRAIRIES

L.M. Arthur[1]

ABSTRACT

A series of physical and economic models is used to simulate the economic effects on Manitoba and Saskatchewan of a prolonged agricultural drought and the potential success of several drought mitigating strategies. A drought scenario, defined in terms of weather events of 1936 to 1940, is compared to a scenario of average normal weather. Results for Manitoba indicate that with new cropping and transportation technologies and 1980 economic conditions the dry weather of 1936 to 1940 would result in a ten percent loss in crop revenues (relative to normal), in addition to losses in cattle revenues due to accelerated culling. The production and employment losses to other sectors of the Manitoba economy averaged eight percent. Results for Saskatchewan are presented primarily in terms of reduced crop yields.

Examination of alternative drought mitigating strategies for Manitoba--conservation tillage in conjunction with one million acres of winter wheat, summerfallowing, and two irrigation projects--suggests that their developmental effects predominate over drought mitigating effects. All of the strategies result in significantly increased gross (but not necessarily net) sales revenues, but only the conservation tillage/winter wheat option stabilized the economy through the five year drought. The use of modern cropping technologies also served to mitigate drought effects in both Saskatchewan and Manitoba.

---

[1] Professor, Department of Agricultural Economics and Farm Management, University of Manitoba, Winnipeg.

SOCIO-ECONOMIC IMPLICATIONS OF A PROLONGED AGRICULTURAL DROUGHT ON THE PRAIRIES

L.M. Arthur and D.F. Kraft[1]

BACKGROUND

Regional economic development in the Prairie provinces is heavily dependent on the performance of the agricultural sector. Primary agriculture accounts for 16 percent of value added for all goods producing sectors in Manitoba, 40 percent in Saskatchewan, and approximately 10 to 15 percent in Alberta (Statistics Canada). Moreover, many other important sectors are strongly linked to agriculture; food and beverage industries, for instance, produced 31 percent of all Manitoba's manufacturing output in 1982 (Manitoba Bureau of Statistics), and still other manufacturers have direct forward linkages to agriculture, providing agricultural machinery, chemicals, and other inputs used by primary agriculture. Transportation and marketing sectors have both forward and backward linkages to agriculture.

The agricultural sector is dependent in turn on weather. In 1983 over 60 percent of the value of Manitoba farm sales, over 80 percent of Saskatchewan's, and nearly 55 percent of Alberta's farm sales were from the crops sector (Canada Grains Council). In all three provinces most of the crop production is dependent on the moisture available from annual precipitation; for example, less than .3 percent of Manitoba's 12 million acres of cultivated cropland is irrigated. Furthermore, livestock production in all the provinces is dependent on native pasture yields and forage production, which are also sensitive to climate. Consequently, the droughts that have occurred periodically in the prairie region have severely disrupted agricultural performance. The extent of this disruption, the resulting impacts on the rest of the economy, and avenues for drought mitigation are the subject of the study described below. Results are presented from the analysis of the impacts of a 1930s type drought on the current Manitoba and Saskatchewan crops sectors and for the entire Manitoba economy with and without new agricultural technologies such as conservation tillage, new irrigation projects, winter wheat production, and decreased summerfallowing.

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[1] Professor and Associate Dept. Head, respectively, Dept. of Agricultural Economics and Farm Management, University of Manitoba.

METHODOLOGY

While little systematic empirical research has been directed at quantifying the effects of drought on regional economic potential, there has been considerable research on some elements contributing to the economic response to drought; for instance, there is a long history of experimentation on the biologic response of crops to moisture stress (e.g., Williams et al.). The available resource-related economic impact analyses have focussed on growth scenarios, such as the regional impacts of irrigation development (Hamilton and Pongtanakorn), coal mining development (Bender et al.), or energy development (Murdock and Leistritz). While these growth models address somewhat different problems than those facing an economy that contracts in the face of drought, their simulation approaches provide a methodological basis for the drought study described below.

The drought study makes use of an extensive system of simulation models similar to that described by Murdock and Leistritz. The major differences lie in the emphasis on economic decline rather than growth and extensive efforts to quantify the impetus to economic decline, rather than merely assuming a level of crop loss for multiplier analysis (see Johnson and Kulshreshtha).

The system of models discussed below includes models of: (1) the impact of weather on soil moisture, (2) the impact of soil moisture and weather on crop yields, (3) the effects of changing yields on farm sector costs, revenues, and output and (4) regional impact of declining agricultural input demands and revenues (Figure 1).[2] Because the complexities of the various models prevent detailed description here, the discussion emphasizes the results of each modelling exercise, the inter-model linkages, and the model of the agricultural sector's economic response to drought.

DEFINITION OF DROUGHT

For this study drought was originally defined in terms of a meteorological event with major impacts on prairie agricultural regions. Weather records for dating back to 1912 were examined and a 1936-1937 drought selected. Farmers in most areas entered 1936 with adequate moisture but the summer was hot and dry, and the dry weather

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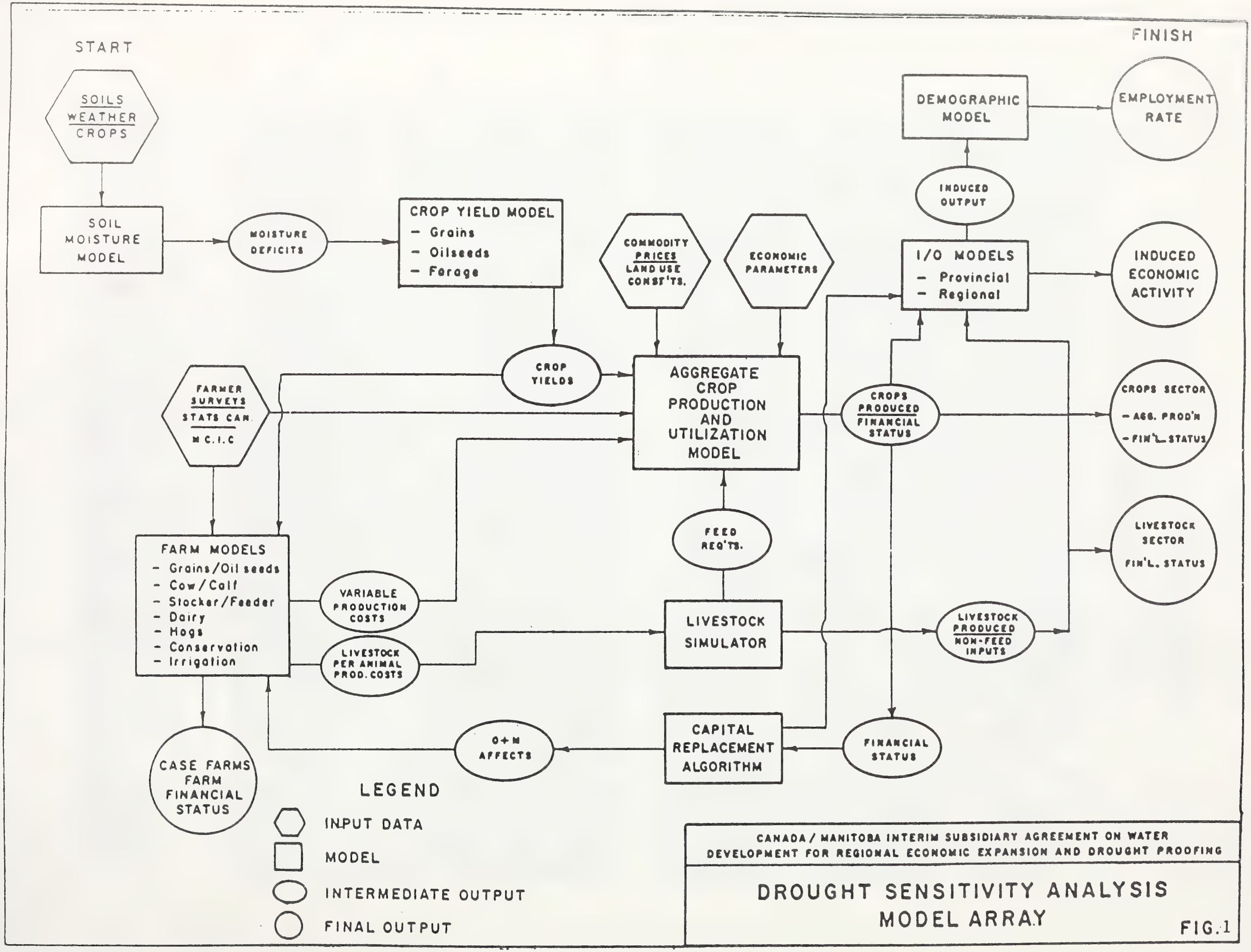
[2] For the Saskatchewan portion of the study, model (3) was not available. Other models used in the Manitoba study include a livestock simulator, farm firm models (which produce some of the production coefficients used in the sectoral model), regional demographic models, and capital equipment replacement algorithms.


START
SOILS
WEATHER
CROPS
SOIL MOISTURE MODEL
MOISTURE DEFICITS
CROP YIELD MODEL
- Grains
- Oilseeds
- Forage
CROP YIELDS
FARMER SURVEYS
STATS CAN
M.C.I.C
FARM MODELS
- Grains/Oil seeds
- Cow/Calf
- Stocker/Feeder
- Dairy
- Hogs
- Conservation
- Irrigation
VARIABLE PRODUCTION COSTS
LIVESTOCK PER ANIMAL PROD. COSTS
CASE FARMS FARM FINANCIAL STATUS
COMMODITY PRICES LAND USE CONST'TS.
ECONOMIC PARAMETERS
AGGREGATE CROP PRODUCTION AND UTILIZATION MODEL
FEED REQ'TS.
LIVESTOCK SIMULATOR
CAPITAL REPLACEMENT ALGORITHM
O+M AFFECTS
FINANCIAL STATUS
CROPS PRODUCED FINANCIAL STATUS
LIVESTOCK PRODUCED NON-FEED INPUTS
I/O MODELS
- Provincial
- Regional
INDUCED OUTPUT
DEMOGRAPHIC MODEL
FINISH
EMPLOYMENT RATE
INDUCED ECONOMIC ACTIVITY
CROPS SECTOR
- AGG. PROD'N
- FIN'L. STATUS
LIVESTOCK SECTOR
FIN'L. STATUS
LEGEND
INPUT DATA
MODEL
INTERMEDIATE OUTPUT
FINAL OUTPUT

CANADA/MANITOBA INTERIM SUBSIDIARY AGREEMENT ON WATER DEVELOPMENT FOR REGIONAL ECONOMIC EXPANSION AND DROUGHT PROOFING

DROUGHT SENSITIVITY ANALYSIS
MODEL ARRAY

FIG.1

Source: Samp 1986

continued through the spring of 1937. During the three years that followed 1937 more "normal" weather conditions returned.

Even a one year drought causes economic adjustments that continue beyond the year of drought. To examine these adjustments a five year scenario was selected, two drought years (1936 and 1937) followed by three more normal weather years (1938-1940). While three normal years may not be sufficient for a farm enterprise to return to an "equilibrium" or "before drought" position, technological and behavioral changes beyond five years are difficult to forecast. The five year drought adjustment scenario is compared to a period of "average normal" weather, defined as the average moisture resulting from 1961-82 weather events. Note that only the weather from these two periods is used; economic and technological factors are in 1979-1981 terms.

DEFINITION OF SCENARIOS

The purpose of this study was to analyze not only the economic effects of a prolonged agricultural drought, but also to determine if certain water conservation and agricultural development strategies would stabilize the economy during such prolonged droughts. This portion of the study was completed only for Manitoba, although similar studies for Saskatchewan have been undertaken by the Prairie Farm Rehabilitation Administration (PFRA). In this study the drought effects on the 1979 Manitoba agricultural sector are compared with economic effects on the same sector with technological changes in place. In addition to the baseline condition, the scenarios that will be discussed here include the following: (a) reduced tillage, snow trapping, and winter wheat production (1.8 million acres[3]); (b) reduction in summerfallowing (810,000 fewer acres[3]); and (c) two small irrigation projects, one in the Carberry Aquifer area of the southwest (100,000 acres) and a 400,000 acre project in the Assiniboine-South Hespler region of southcentral Manitoba. All of these scenarios are small in scale relative to aggregate provincial production and each will have its major effects in a smaller region (e.g., irrigation within the defined projects, snow trapping in the dry regions of southwestern Manitoba, reduced summerfallow in areas where significant summerfallowing now occurs). Although these regional effects were analyzed, only aggregate results can be reported here.

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[3] This area was selected in the linear programming procedure, depending on net returns from reduced versus normal tillage.

METHOD AND RESULTS

Simulation of Moisture Conditions

The translation of a meteorological drought into an agricultural drought depends on the moisture stress experienced by various crops under varying conditions of rainfall, heat, light, and soil texture, inter alia. Crop moisture shortfalls are defined in terms of the amount of moisture a given crop would have utilized if the water had been available. Thus, the timing as well as the magnitude of the shortfall will determine crop response.

The moisture response model is based on Agriculture Canada's daily meteorological data (precipitation and temperature) from 188 Prairie weather stations and its Versatile Soil Moisture Budget (VSMB, Baier and Robertson). Soil moisture shortfalls (by soil type) are estimated to change as a function of potential evapotranspiration, crop rooting pattern, available soil moisture, and soil moisture release characteristics, which can vary across scenarios with the change in certain moisture conserving technologies, such as snow trapping and summerfallowing. The VSMB model operates continuously (daily) throughout the year, taking into account precipitation and runoff as well as snow accumulation and rate of snow melt under the various weather and technology conditions, including scheduled applications of water in the irrigation scenario.

Moisture shortfalls calculated using the VSMB for the 1936-1940 period show a continuing pattern of drought; total shortfalls on wheat in crop reporting district (CRD) 3 in Manitoba's southwest (Figure 2), for instance, range from 174 mm (1937) to 256 mm (1936) in the "drought" scenario compared to 130 mm under average "normal" conditions. In southern Saskatchewan shortfalls reach 485 mm under 1936 conditions (crop subdistrict 4A, Figure 3), compared to a 20 year average of 272 mm for the same crop district. Moisture conserving technologies reduce the stress considerably, however; with summerfallowing total moisture shortfalls during the drought years in Manitoba's CRD 3 range from 154 to 214 mm, while under reduced tillage and snow trapping they range from 162 to 223 mm. In the scenarios analyzing potential irrigation projects, irrigation is scheduled to reduce average moisture stresses to near zero.

Crop Yield Models

Soil moisture deficits represent only one of the factors influencing crop yields; other factors include fertilizer use, extreme weather events such as frosts and excess moisture, pest problems,

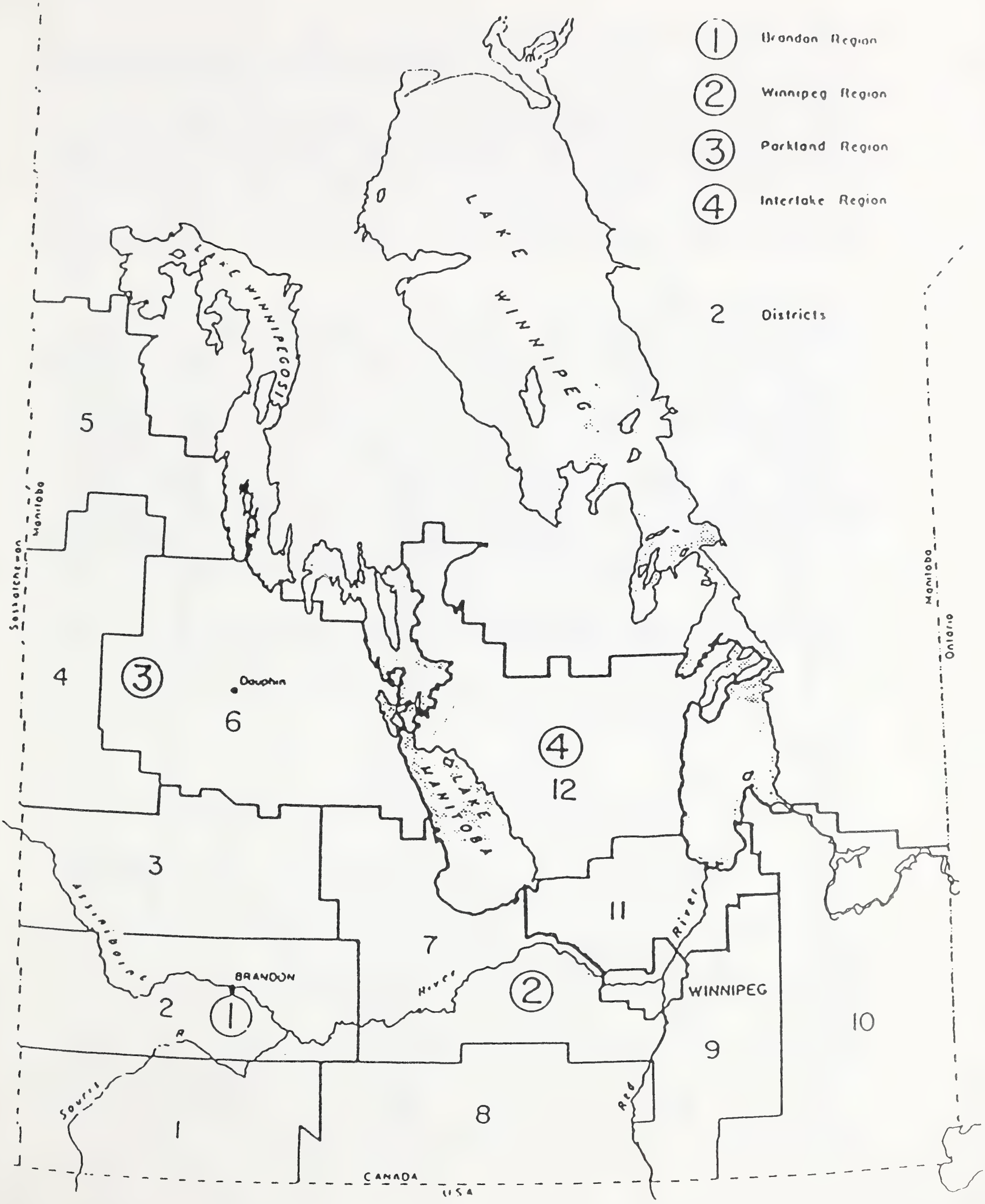
① Brandon Region
② Winnipeg Region
③ Parkland Region
④ Interlake Region
2 Districts
LAKE WINNIPEG
LAKE WINNIPEGOSIS
LAKE MANITOBA
Dauphin
BRANDON
WINNIPEG
Assiniboine
River
Red River
Souris
Saskatchewan
Manitoba
Ontario
CANADA
USA
1
2
3
4
5
6
7
8
9
10
11
12
①
②
③
④

Figure 2: Manitoba Crop Reporting Districts And Study Regions

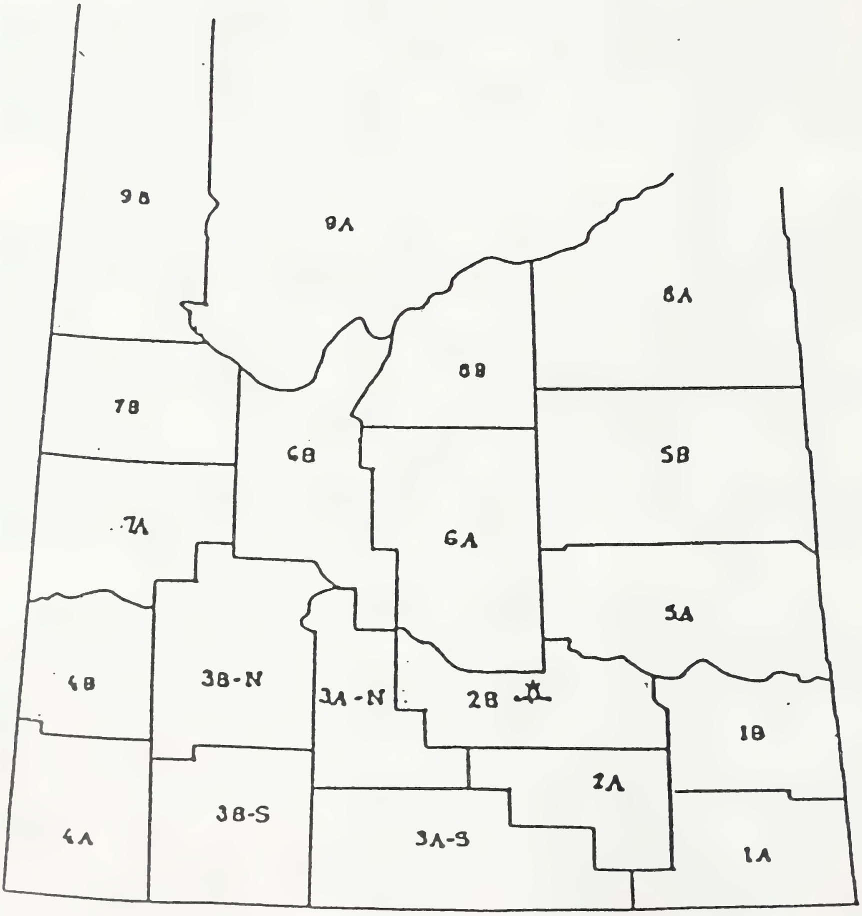
9B
9A
8A
8B
7B
6B
5B
7A
6A
5A
4B
3B-N
3A-N
2B
1B
2A
4A
3B-S
3A-S
1A

Figure 3. Saskatchewan Crop Sub-Districts

variety selection, etc. The crop yield models quantify these relationships via regression models.

Separate equations were run for most of the 11 major crops (grain, oilseeds, forages) by seedbed (i.e., stubble and fallow), as well as for winter wheat in Manitoba. The 1980-1981 technology is imposed on the models through the variables for genetic improvement, fertilizer use, and fallowing rates. That is, in predicting yields for 1930's and 1950's weather patterns under 1980 technology, average 1980-1981 fertilizer use, varietal distributions, and summerfallowing rates are used.

Yields vary substantially by year, region, and technology in response to varying moisture shortages. For example, the southwest region suffers the most moisture stress in Manitoba and hence, the highest yield losses under 1930s conditions (see Table 1), and thus also has the most to gain from moisture conserving or adding technologies. Summerfallowing can increase wheat yields by over 50 percent in the southwest in a 1936 type drought, (compared to less than 15 percent in average normal weather), and reduced tillage/snow trapping can increase drought yields 16 percent (compared to reducing yields in wet weather). Irrigated corn yields can more than double and alfalfa yields quadruple over dryland yields under drought conditions. In Saskatchewan the entire southern region suffers during the 1930s weather.

Table 1. Predicted Wheat Yields on Stubble in Manitoba and Saskatchewan Crop Reporting Districts: Baseline Scenario

Year	Manitoba			
	CRD 1 (SW)	CRD 4 (SC)	CRD 7 (NW)	CRD 12 (NC)
	(tonnes/acre)			
1961-1980 average	.74	.75	.85	.74
1936	.41	.48	.75	.68
	Saskatchewan			
	CD 2A (SW)	CD 4B (SE)	CD 6A (C)	CD 9A (N)
1961-1980 average	.68	.52	.48	.53
1936	.39	.42	.48	.40

The yields in Table 1 reflect the regionality of the 1936 drought (dominating the southern area of the provinces only), as well as the variation in expected normal yields. The high 1936 yields in northern crop districts will buffer drought effects in southern regions, while in 1937 a western drought is buffered by high yields in eastern regions. Thus, provincial drought impacts will not be as dramatic as some impacts in smaller regions.

Agricultural Response to Drought

The regional agricultural response to drought cannot be obtained by summing responses of individual farm enterprises, due to varying interfarm trading patterns. For instance, a grain farm may sell all of its crop into export markets in a normal year, but during a drought may sell grains as feed to a neighboring livestock farm; thus, the southwestern grain farm's revenue becomes the southwestern livestock enterprise's cost, but only in certain drought conditions. An aggregate model of the agricultural industry in Manitoba was developed to accommodate these changing trading patterns and to constrain total production to known resource endowments and historic export levels.

The aggregate agricultural model is in linear programming (LP) format and is used to maximize net regional agricultural incomes subject to resource and marketing constraints and simulated crop yields. The five year model is solved annually, with closing inventories in one year becoming endowments for the following year. Each annual solution requires two runs. The first solution determines the aggregate management decisions (e.g., crop mix) based on farmers' expectations for a "normal" weather year. In the subsequent run adjustments are made due to the effects of drought (e.g., livestock are culled, grain revenues decline).

The solution to the LP model yields a mix of crop and livestock outputs, as well as aggregate expenditures and sales for the respective regions. To illustrate, the aggregate crop sales for the province under four scenarios are presented in Table 2. Although production volumes are significantly lower under the drought conditions in all scenarios, aggregate sales are stabilized somewhat in the worst year of drought (year 1, 1936 conditions) because on-farm inventories (assumed in place before the drought) could be depleted to meet quotas. Thus, the second drought year shows the lowest sales values because inventories were exhausted in the previous year.

Table 2. Manitoba L.P. Solution: Gross Sales of Grains and Oilseeds

	Scenario			
Weather	Conventional Technology	Irrigation Projects	Reduced Till, Winter Wheat	Reduced Fallow
		(million 1979$)		
Normal Weather	1216	1328	1274	1299
Drought (1936)	1097	1236	1194	1175
Drought (1937)	1015	1147	1118	1059
Drought (1938)	1181	1286	1266	1239
Drought (1939)	1103	1243	1208	1163
Drought (1940)	1096	1209	1178	1148

Unfortunately, gross sales alone do not represent accurately the health of the agricultural sector. During periods of drought sales revenues decline up to 18 percent, but on-farm costs remain nearly constant, or even increase (e.g. due to higher feed costs) over normal levels. Thus the farmer's net position is much worse than that indicated by gross sales

Even aggregate net cash flow after expenses does not fully reflect the farm sector's position following a drought. Increased livestock sales (from accelerated culling) and inventory-buffered grain sales result in much lower on-farm stocks (grain and oilseed inventory values are depleted by $173 million to $211 million in the year following the 1936 drought, depending on the scenario), leaving farmers more vulnerable in the year following drought. Further, farm equipment that was not replaced is a year older and will eventually have to be replaced, and operating debts that could not be repaid will continue to incur interest. Thus, if other financial strains occur, farmers will suffer greater losses due to the stock effects of the drought.

The three alternative technology scenarios show small developmental effects on gross sales, but increases in variable and fixed costs under these scenarios reduce the net advantage. In fact, one of the irrigation projects produces negative returns in the irrigated regions if capital equipment is maintained.[4] All the scenarios show substantial provincial net income declines during the drought period, partially due to the relatively small scales of the changes (e.g., irrigation of 500,000 out of 12 million acres). Only the conservation and winter wheat scenario shows any significant income stabilization during drought; returns over variable expenditures decline an average of 24 percent during droughty years, versus 30-38 percent declines during drought in the other scenarios.

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[4] Under other cost/price structures, increased returns may accrue, but for 1979-86 conditions irrigation does not pay.

Beyond the Farm Gate

Farm enterprise demands for inputs and farm household demands for consumer goods and services stimulate additional economic activity in the regional and provincial economies. The relationship between the economy beyond the farm gate and the agricultural sector is modelled in a series of input-output (I-O) models, based on the structure of Statistics Canada's I-O models for the Prairie provinces (Statistics Canada 1982) and the outputs from the aggregate agricultural models (including the livestock simulation not discussed here). In addition to the provincial models, I-O models were developed to represent four agricultural regions of Manitoba and three regions of Saskatchewan. The I-O models are rectangular, varying in size from 18 endogenous sectors by 34 endogenous commodities to 49 sectors by 67 commodities, depending on the economic structure of the region. The rectangular structure permits the modelling of production of any given commodity by more than one industry (described in a "market share" matrix), as well as the modelling of commodity-based production functions (technology matrix).

Before solving the I-O model, the agricultural sector, including farm households, is made exogenous (other households are endogenous). Because the agricultural sector (including agricultural incomes on which farm household consumption is based) is "optimised" outside the I-O model (in the LP model), the further adjustments that would take place in an endogenous sector are not desirable. Using only this exogenous agricultural sector as a final demand vector (i.e., all other final demands remain constant across scenarios) results in a measure of the agricultural multiplier effect and agriculturally induced economic activity.

Sample results from the Manitoba I-O models for drought and normal years are presented in Table 3 in 1979 dollars. The type II output multiplier for agriculture is estimated at 2.4; that is, for every $1 of expenditure in the province an addition of $1.40 of output is generated to service that expenditure. Total agriculturally linked output is approximately $2 billion in the baseline condition under normal weather (Table 3). Over a series of drought years output declines 8 percent and unemployment rises nearly one percentage point over the base level, representing approximately 4000 agricultural and nonagricultural jobs. While farm enterprises spend more on feed in the drought year, other input expenditures (with greater interindustry linkages) decline, particularly the more discretionary expenditures of farm enterprises and households, such as the purchases of new farm equipment, new cars, household appliances, etc. The type II multiplier for Saskatchewan is estimated to be 2.0 (Johnson and Kulshreshtha), compared to 1.14 for gas and oil, 1.5 for pulp and paper and 1.5 for crude metals.

Table 3. Provincial Output Induced by Agriculture

Weather Condition	Scenario			
	Conventional Technology	Irrigation Projects	Reduced Till, Winter Wheat	Reduced Fallow
	(million $)			
Normal	2052	2196	2109	2140
End of 1936-40	1888	2015	1958	1953

Again, the alternative technologies examined in the Manitoba portion of the study show developmental effects on the agriculturally linked sectors (due to increased expenditures), but only the reduced tillage/winter wheat scenario shows any drought stabilizing effect during droughts.

These effects can be disaggregated sectorally. While on a percentage basis, most of the major sectors suffer similarly during drought, the relative magnitudes of the various sectors and their labour intensities result in heavy employment losses in the trade and service sectors; the retailing sector alone accounts for nearly half the non-agricultural man years lost due to drought. Because many retailing jobs are part-time, substantially more actual employees could be affected.

CONCLUSION

The agricultural sector of Manitoba and Saskatchewan would be affected severely by droughts of a 1936-1937 magnitude, despite new technologies--both those currently employed (versus those used in the 1930s) and those only now being considered and adopted--and despite the regional specificity of the 1936 and 1937 droughts. The losses to the agriculturally linked sectors of the economy are buffered somewhat by the stable input demands of farmers even during periods of drought, but are substantial (e.g., 7-9 percent of output during 1936 to 1940 weather in Manitoba) nonetheless. Reduced tillage and winter wheat production offer promise of slightly increased economic stability during drought (if new disease and pest risks and winter kill do not severely disrupt production), but the developmental effects of these and other technologies examined in this study predominate over stability effects. The most significant drought stabilizing effects were from use of 1980s cropping technologies, particularly new drought resistant varieties and summerfallowing.

ACKNOWLEDGEMENTS

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RECENT WEATHER ON THE CANADIAN PRAIRIES AND ITS EFFECTS ON AGRICULTURE

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Abstract: Many of the seemingly unrelated events of irrigation water-supply problems, grasshopper infestations, reduced grain quality and crop failures of the last three years in western Canada are related to a sequence of climatic events. Even before the 1984 growing season began, analysis of precipitation data, overwinter soil moisture measurements, snowpack surveys, river-flow data, and grasshopper survey information indicated that the potential existed for serious agricultural problems in the southern prairies. Examination of historical data indicated that in some locations the droughts of 1984 and 1985 were as severe as those encountered during the 1930's. The effects on agriculture, however, were much different.

INTRODUCTION

The major factors affecting crop growth include soil moisture supply, soil nutrient status and an agriculturallly favourable climate. When water supply is not limiting, crop response to supply of nutrients, especially nitrogen, is enhanced. An agricultural climate must provide a favourable environment for crop production with a minimum risk of crop loss. Although such factors as temperature and length of growing season are important climatic constraints on agriculture, abundant moisture supply is the most essential consideration.

When examining issues of water resources especially, those concerning agriculture, climate is one of the most important aspects to be considered. Often the effects of climate on agriculture are many and seemingly unrelated. The effects of recent weather on the Canadian prairies have been dramatic: droughts, crop failures, grasshopper infestations, wet harvest conditions, and some of the worst wind erosion of soils since the 1930's.

In the west, the summers of 1984 and 1985 were marked by droughts across southern Alberta and Saskatchewan. Dryland crops dried up before harvesting and millions of dollars in lost production were reported. Even farmers who irrigated had trouble keeping sufficient water on their fields in 1984 because some irrigation districts could not supply enough water to meet the demands. Added to the drought problem, there was a severe grasshopper infestation. Although serious grasshopper infestations continued in many areas of southern Alberta and Saskatchewan in 1986, crop yields rose to near record levels.

In the eastern and northern areas of the prairies, conditions were often much different. Southern Manitoba reported above average precipitation during the 1984 and 1985 growing seasons. For example, compare the 1984 and 1985 June precipitation of Winnipeg (228 mm and 72 mm) with precipitation in Lethbridge (53 mm and 2 mm). Similarly, the northern part of the prairies tended to be wetter.

A synthesis of data from various sources is presented here to illustrate some of the interactions of climatically related variables and their effect on agriculture in western Canada. Data from southern Alberta are used to demonstrate specific interactions.

DROUGHT

A drought may be defined as a period of time with below-average precipitation. Factors other than precipitation, such as potential evaporation and soil-water storage, are also important. For example, pan evaporation is often double and triple the precipitation rates for many prairie locations (Figure 1). Because precipitation varies with time, it is reasonable to expect droughts periodically.

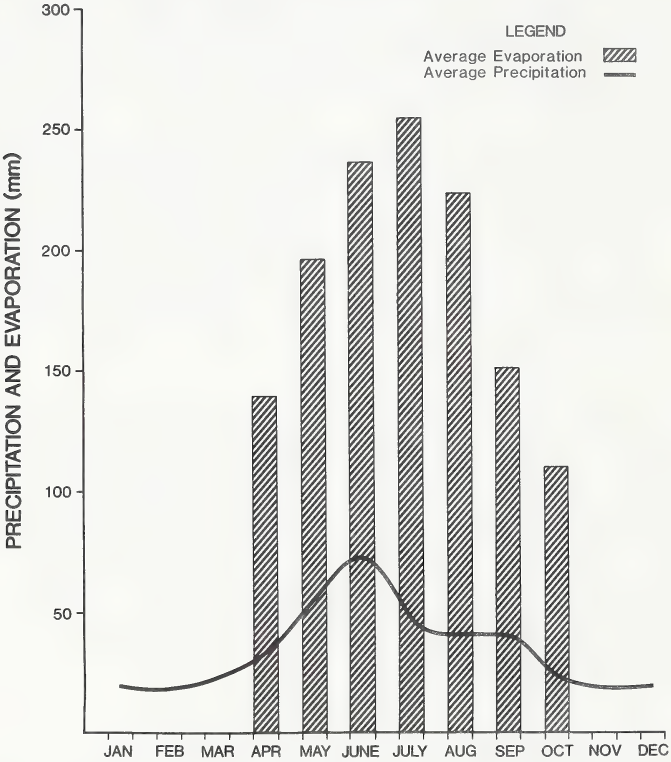

Figure 1. Growing season pan evaporation and average precipitation for Lethbridge, Alberta.

A. Soil Moisture

When considering the effects of drought on agriculture it is important to remember that it is not just the lack of rain that causes a drought but rather the timing of precipitation events (Grace and Johnson, 1985; Grace, 1986). Certainly, any one year may have above-normal precipitation, but if it occurs at a time when crops cannot utilize the moisture then the rainfall is of little use and a drought can ensue. If any single precipitation event is followed by very hot, dry, and windy weather then most of the moisture evaporates. The rainfall is then of little use to the crop. Such an event occurred during June 1984 in southern Alberta. Twenty four millimeters of rain fell in Lethbridge on June 21. This was followed by a week of clear, hot (27 to 34°C), dry (21 to 34 % RH), and windy (30 to > 70 km/h) weather. Within a few days much of the moisture provided by the rain was lost to the atmosphere and crop damage proceeded. For the crops, the rainfall had little significance.

Soil moisture, therefore, is the key in assesing drought conditions for crops. For example, the 1974 growing season (May to July) in Lethbridge was dry with only 52% of normal rainfall being recorded. Average and above-average crop yields were reported for that year. Soil moisture reserves were adequate during the dry growing season owing to above-normal precipitation in late winter.

B. Recent Crop Years

Often the effects of drought or dry spells are many and seemingly unrelated. The droughts of the summers of 1984 and 1985 are discussed here as examples.

The droughts of 1984 and 1985 followed completely different climatic patterns. Since crop growth normally removes all available moisture from the soil during each growing season, dryland farming operations depend on precipitation during the fall and winter to ensure adequate soil moisture reserves at planting time. Irrigation systems also rely on overwinter moisture accumulation to replenish reservoirs and build snowpack in the mountains to ensure sufficient stream flows during the spring and summer months. Therefore, in examining droughts it is necessary to begin in the previous year, after harvest.

The 1983-84 Crop Year

The 1983-84 fall and winter period was one of the driest on record in many areas of the southern prairies. The sunny, dry weather of August, 1983 provided excellent conditions for grasshopper breeding and egg-laying. The greatly reduced precipitation (Figure 2) resulted in little moisture stored in the soil. In addition to the lack of moisture, above-normal temperatures were recorded in southern Alberta for January, Feburary and March. Mild winter temperatures resulted in a low mortality rate for grasshopper eggs. The combination of above-freezing temperatures, high winds, and low humidity depleted any soil moisture reserves that had accumulated.

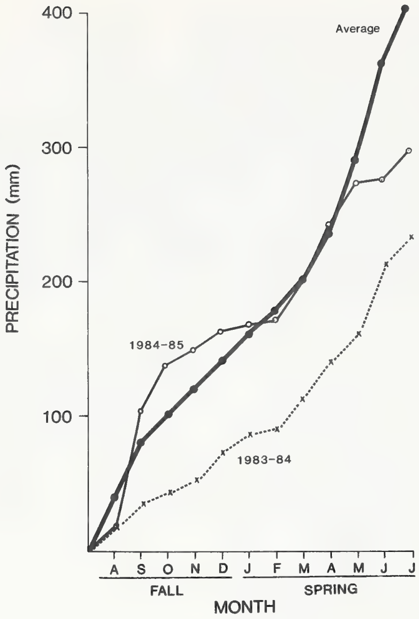

Figure 2. Accumulated precipitation for the 1983-84 and the 1984-85 crop years at Lethbridge, Alberta.

During the same period, poor snow pack conditions in the mountains were 48 to 61% of normal (Table 1). The potential problem for irrigation water supply was apparent. Above-average precipitation for the spring months was required to ensure normal crop development for dryland crops and to provide adequate stream flow for irrigation systems. Unfortunately, below-normal precipitation was recorded for the months of April, May, and June, with May rainfall being less than half the average for many southern locations. Data for Alberta are presented in Figure 3 and Table 2 to give an indication of precipitation patterns. The warm and dry spring weather of 1984 produced dramatic increases in the grasshopper populations due to rapid growth and high survival of the nymphs.

Table 1. Snowpack: March 27, 1984

Sampling location	1984	21-year mean	Percent of normal
Wilkinson Summit	99	189	52
West Castle	226	474*	48
Allison Pass	307	504	61

* mean of 18 years of data
Amounts given in mm water equivalent.
Data courtesy of River Forecast Center, Alberta Environment.

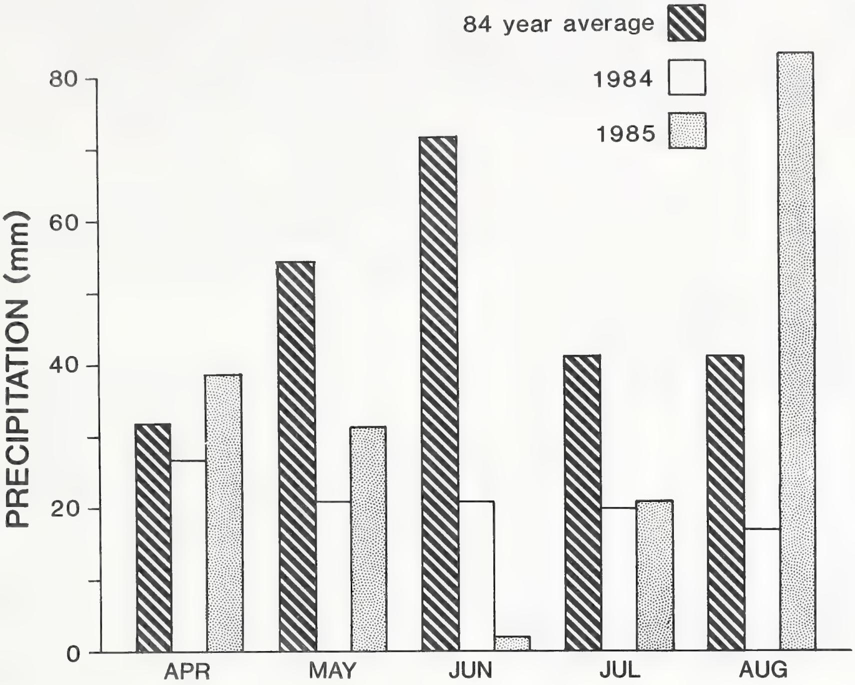

Figure 3. Growing season precipitation for 1984 and 1985 recorded at Agriculture Canada Research Station, Lethbridge, Alberta.

Table 2.

Alberta summary of growing season precipitation (mm)to July 23, 1984

Location	Actual	Normal	Percent
Lethbridge	72.7	169.0	43
Vauxhall	70.2	123.8	57
Manyberries	65.2	129.8	50
Foremost	84.0	139.2	60
Medicine Hat	86.8	136.1	64
Calgary	157.5	185.9	85
Edmonton	170.3	180.5	94
Beaverlodge	169.5	159.4	106

Data courtesy of Alberta Agriculture.

The limited soil moisture reserves of early spring (Figure 4) were largely depleted by early summer, a time when cereal crops require high amounts of moisture for reproductive growth and grain development. However, instead of receiving the needed rain, the southern parts of the prairies entered a dry period. A total of 36 days without precipitation was recorded at Lethbridge from June 23 to July 28 (Table 3).

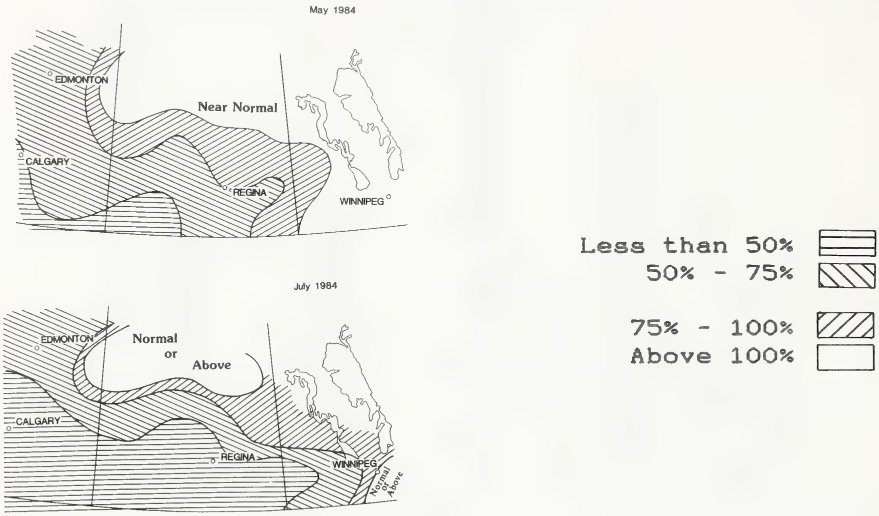
May 1984
EDMONTON
Near Normal
CALGARY
REGINA
WINNIPEG
July 1984
EDMONTON
Normal
or
Above
CALGARY
REGINA
WINNIPEG
Normal or Above
Less than 50%
50% - 75%
75% - 100%
Above 100%

Figure 4. Computer estimation of percent available moisture under stubble conditions for May and July 1984. Data courtesy of Agriculture Canada, Land Resource Research Institute, Ottawa. (Soil Moisture Evaluation Program)

Table 3.

Duration of dry conditions at Lethbridge in the June and July growing period (1936 - 1984)

	Less Than 0.1 mm of Precipitation	
Year	Period	Duration
1979	Jul 14 to Jul 24	10 days
1977	Jun 17 to Jun 27	10 days
1957	Jul 17 to Jul 29	12 days
1947	Jul 04 to Jul 23	17 days
1960	Jul 04 to Aug 01	28 days
1984	Jun 23 to Jul 28	36 days

Owing to the reduced snow pack conditions, stream flow in the Oldman River for June was reported at 52% of normal and 50% for July (Anon, 1984). As a result of reduced supply and increased demand, the Lethbridge Northern Irrigation District (LNID) required four general system shutdowns during the summer of 1984. This was the most times the LNID was forced to cease operation in one year since it began service in 1924. Only once before (1983) did it close twice in one season.

As a result of the sequence of climatic conditions described here, dryland crops failed, grasshopper populations increased, and irrigation problems were reported in the southern prairies in 1984.

The 1984-85 Crop Year

Above-normal precipitation in September and October of 1984 replenished the soil moisture reserves (Figures 2 and 5). This, combined with near normal early spring precipitation in 1985, ensured good soil moisture conditions at planting time. Average to above-average snowpack conditions were reported in the mountains so that conditions were favourable for a good growing season. However, the dry, sunny conditions of the previous summer combined with a large population of grasshoppers again resulted in forecasts of major grasshopper infestations (Figure 6).

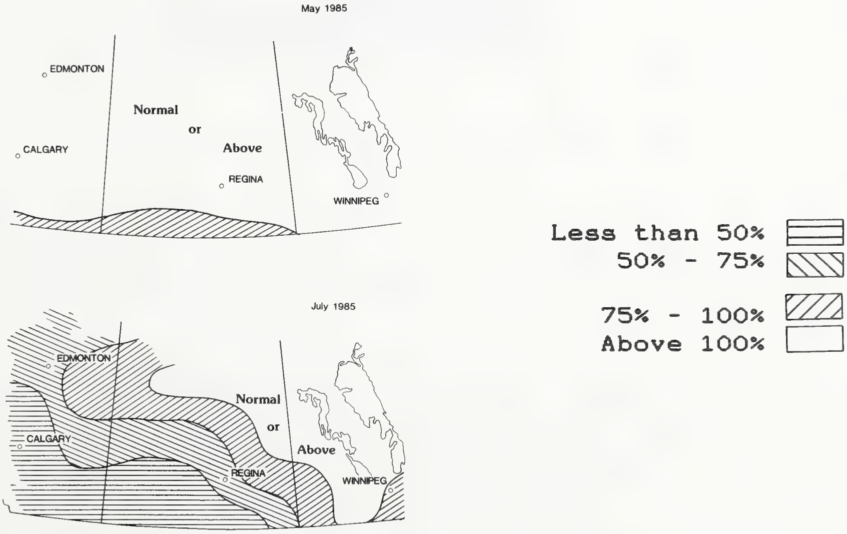

Figure 5. Computer estimation of percent available moisture under stubble conditions for May and July 1985. Data courtesy of Agriculture Canada, Land Resource Research Institute, Ottawa. (Soil Moisture Evaluation Program)

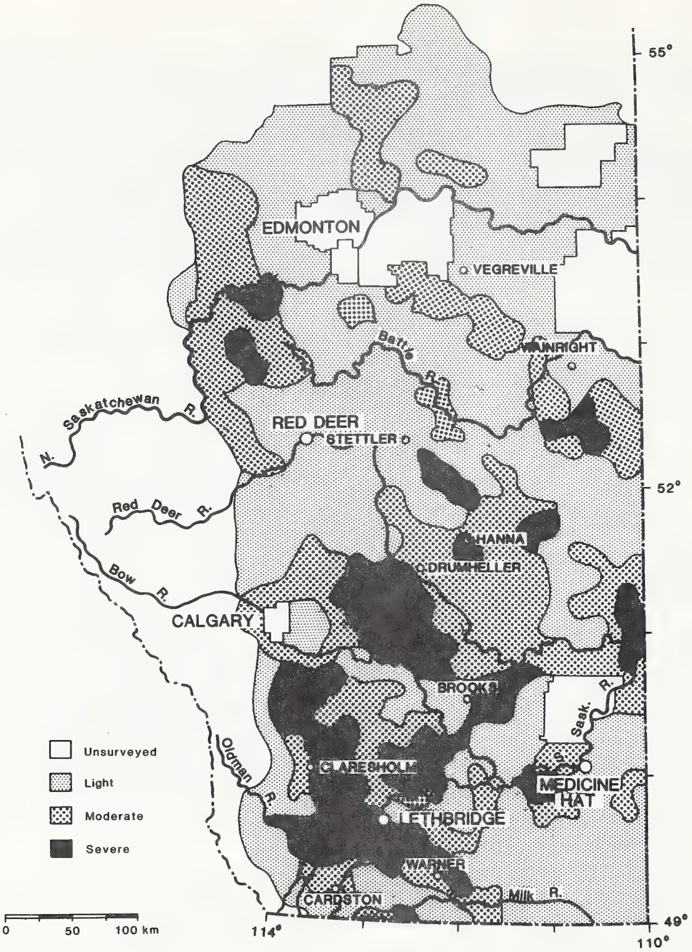
55°
EDMONTON
VEGREVILLE
Battle R.
WAINRIGHT
N. Saskatchewan R.
RED DEER
STETTLER
52°
Red Deer R.
HANNA
DRUMHELLER
Bow R.
CALGARY
BROOKS
S. Sask. R.
Oldman R.
CLARESHOLM
MEDICINE HAT
LETHBRIDGE
WARNER
CARDSTON
Milk R.
Unsurveyed
Light
Moderate
Severe
0
50
100 km
114°
110°
49°

Figure 6. The 1985 Alberta grasshopper forecast (Johnson and Andrews, 1984).

Problems with wind erosion of soils became serious during the 1984-85 winter, especially in the chinook belt of southern Alberta where strong winds are common at that time of the year (Grace and Hobbs, 1986). The crop failures of the previous summer left little crop residue to protect the soil.

Although good soil moisture reserves were reported for early spring 1985 (Figure 5), little agriculturally significant precipitation was recorded for many southern locations from mid-May to the end of July. For example, only 2 mm was observed at Lethbridge, Alberta in the critical month of June, traditionally the wettest month of the year with an average of 73 mm (Figure 3). This was the lowest June precipitation ever recorded in the 83-year history of the Lethbridge Research Station. Again, many dryland crops failed. Those that produced a yield did so on soil moisture reserves alone.

The dry, sunny weather favoured the rapid development of grasshoppers and major control programs were required. Yields of forage crops and pasture production were also very poor. As carry-over reserves of feed from the previous year were low owing to the 1984 drought, feed prices rose dramatically.

Owing to abundant water supply from the mountains, few problems were reported from producers with irrigated land; many excellent yields were reported. However, abnormal precipitation in the late summer and early fall of 1985 interfered with harvesting operations and major losses were reported as a result of grade deterioration (see below).

Thus, similar crop failures and insect infestations were reported for two climatically different years, one with small soil moisture reserves in the spring and below-average growing season precipitation, and another with excellent soil moisture reserves in the spring but almost no significant precipitation during the critical portions of the growing season.

The 1985-86 Crop Year

Well above average precipitation was recorded during August and September 1985 (191 mm were recorded vs the long-term average of only 81 mm for this period) (see Figure 3). This rainfall replenished the depleted soil moisture reserves. Much of this moisture was locked into the soil with the freezing temperatures of November, the coldest November on record with average daily temperatures of -13°C. Little of this moisture was lost during the mild December and January and remained in the soil as a moisture reserve for spring planting. Spring and summer precipitation was adequate to ensure record production in many areas.

With two summers of drought and poor crops, the lack of crop residue resulted in an increase of soil erosion by wind. Especially susceptible were fields that were in fallow during the 1985 summer and had little initial crop residue owing to crop failure in 1984.

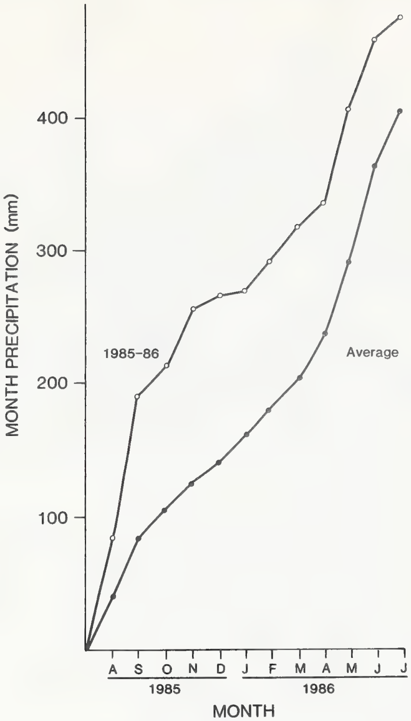

Figure 7. Accumulated precipitation for the 1985-86 crop year at Lethbridge, Alberta.

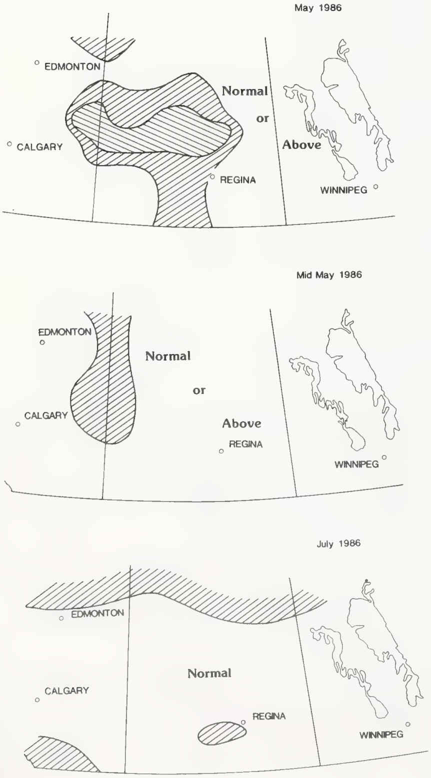
May 1986
EDMONTON
Normal
or
Above
CALGARY
REGINA
WINNIPEG
Mid May 1986
EDMONTON
Normal
or
Above
CALGARY
REGINA
WINNIPEG
July 1986
EDMONTON
Normal
CALGARY
REGINA
WINNIPEG

Figure 8. Computer estimation of percent available moisture under stubble conditions for May, mid-May, and July 1986. Data courtesy of Agriculture Canada, LRRI, Ottawa. (SMEP)

Less than 50% ▤
50% - 75% ▧

75% - 100% ▨
Above 100% ☐

The grasshopper outbreak, which had been increasing in severity since 1983, had slowed. The cool, wet weather of August and September 1985 interfered with the egg-laying activities of the insects. Although the areas affected and rated as severe did not decrease dramatically, the level of infestation was generally reduced. Whereas the grasshopper population still remained high with serious outbreaks in some areas of southern Alberta and Saskatchewan, it did not increase.

The level of snowpack in the mountains, especially the accumulation of snow at high elevations, was only slightly below normal and no major water supply problems for irrigation were encountered.

C. Crop Losses

Across southern Alberta and Saskatchewan crop losses and reduced yields were reported during the summers of 1984 and 1985. The magnitude of damage caused by the drought conditions is difficult to assess. The Alberta Wheat Pool reported that an estimated million acres of land were taken out of production in southern Alberta alone during the summer of 1984. Reduced yields in 1984 and 1985, especially in southern Alberta and Saskatchewan, resulted in a total production of less than 40 million tonnes (all wheat) in western Canada (Table 4).

Table 4.

All wheat yields (bu/ac) and production (million tonnes)

	1984	1985	1986
Western Canada Avg.	23.3	25.2	32.0
Province			
Alberta	24.6	23.0	35.1
Saskatchewan	21.1	22.6	30.4
Manitoba	30.9	40.0	36.7
Total Production			
Western Canada	36.0	40.6	52.0

Data Courtesy of the Canadian Wheat Board.

Yield and production data from southern Alberta are presented in Tables 5 and 6 to indicate the effects of the 1984 and 1985 droughts. Although the acreage of wheat planted in southern Alberta was slightly higher than the 5 year average (Table 5), both yields and total production were low relative to previous years. Total production of all wheats was reduced by almost one million tonnes in the southern crop districts.

Examination of 1983, 1984 and 1985 crop data for the Lethbridge Crop District shows that the yields for all of the major cereal crops, even those traditionally grown on irrigated land, were below the 1983 levels. The most dramatic decrease in yields occurred on dryland crops such as hard red spring wheat, 46% reduction in 1984 and 52% in 1985 (Table 6). Many of these crops, however, were not harvested and as a result are not included in the average yield data. For example, the total acreage harvested for hard red spring wheat in 1984 and 1985 was only 50% of the 1983 total. Some crops had such poor yields that they were left standing in the fields, whereas others were cut for forage (Grace, 1985). Some producers turned their cattle on to their dryland fields.

Table 5.

Production data, six southern Alberta crop districts

5-year averages vs 1984 and 1985

	Yield (kg/Ac)			Acreage(x1,000,000)			Production		
	Avg.	1984	1985	Avg.	1984	1985	Avg.	1984	1985
All wheats	892	625	641	3.6	3.9	3.9	3.2	2.4	2.5
Barley	1096	676	773	1.7	1.3	1.5	1.9	0.9	1.1

Production data in millions of tonnes.
Data courtesy of the Alberta Wheat Pool.

Table 6.

Production data for the Lethbridge - Brooks crop district

1983 vs 1984 and 1985

	Yield (bu/Ac)			Acreage (x1000)		
	1983	1984	1985	1983	1984	1985
Soft White Spring	66*	52.3	63.6	NA	294	300
Hard Red Spring	38.7	20.9	18.7	724	369	324
Durham	32.8	20.1	19.3	165	177	188
Winter Wheat	30.2	27.6	22.7	81	146	141
Barley	55.3	43.8	50.0	262	180	294

* Approximate Value

Data courtesy of the Alberta Wheat Pool.

Note: 45.93 bu barley per tonne
36.74 bu wheat per tonne

GRADE DETERIOATION

The poor harvest conditions in the southern prairies these past two years dramatically illustrated the importance ofan untimely excess of precipitation. For example, southern Alberta received twice the normal precipitation (190 mm vs mean of 80 mm) for the August and September 1985 harvest period. The timing of rainfall was evenly spaced at regular intervals so that crops could not dry in the fields for harvest. As a result of grain swelling and sprouting, the crop quality deteriorated. Very little of the harvest met grades 1 and 2, most being downgraded to feed grain (Table 7).

A change in precipitation patterns from the previous two years was noted during the 1985-86 crop year for much of the prairies and above-average yields were reported. For example, the total production of grains in Alberta was a record 17.8 million tonnes, exceeding the 10-year average by more than 4 million tonnes, and the 1985 production by more than 6 million tonnes.

Table 7.

Percent grade soft white spring wheat at selected locations in southern Alberta, 1985

	Grade			
Station	1 Canada	2 Canada	3 Canada	Canada Feed
Coaldale	20%	15%	15%	50%
Lethbridge	5	5	20	70
Taber	20	15	10	55
Vauxhall	30	55	5	10

Data courtesy of the Alberta Wheat Pool.

Unfortunately, above-average rainfall in the critical harvest time of late August and September resulted in poor grades of cereals across much of the west. Southern Alberta precipitation during the month of September ranged from 250 to 650% of normal. As a result, August estimates of over 75% of the hard red spring wheat being graded at #1 and #2 were incorrect. In fact, less than 25% made these grades, with the majority of this year's crop being downgraded to grade #3 or Canada Feed grade (Table 8). An estimated $160 million have been lost to Alberta producers owing to the poor harvest conditions and grade deterioration.

Table 8.

Percent grade hard red spring wheat in Alberta

	10-yr Avg.	1985	1986 (Est.)	1986 (Act)
1 Canada	32	12	51	17
2 Canada	22	15	25	10
3 Canada	30	51	20	39
Canada Feed	16	22	4	34

Data courtesy of the Alberta Wheat Pool.

GRASSHOPPERS

Climatic conditions that resulted in drought and crop losses in 1984-85 were also responsible for the severe grasshopper outbreaks experienced across the prairies in June - August, 1984-85. The grasshopper population had been on the increase since 1978, based on annual surveys of breeding populations found at the begining of August, and increased dramatically in 1983, 1984 and 1985 (Figure 9).

The sunny, dry weather of August, 1983 provided excellent conditions for grasshopper breeding and egg-laying. The eggs are laid in pods 2 to 5 cm deep in the soil, and hatch the following spring. Temperatures below -20°C at this depth will cause the eggs to freeze, especially if the cold remains over extended periods. However, the effects of air temperatures below -20°C in December, 1983 were ameliorated by an insulating layer of snow. Soil temperatures at the Lethbridge Research Station, for example, never fell below -11°C at a depth of 5 cm. Temperatures in January and Febuary were above normal, and consequently the rate of mortality of overwintering grasshopper eggs was low. Eggs collected in Febuary 1984 showed nearly 90% survival, as compared to values as low as 12% recorded in past years (R. M. White, unpublished data).

Reduced mobility and growth rates, as well as the increased risk of fungal infections, during cool wet spring weather are known to increase grasshopper nymph mortality. It is well known that while a wet spring can result in the virtual disappearance of a large population of young grasshoppers, warm and dry spring weather such as occurred in 1984 and 1985 can produce dramatic population increases due to rapid growth and high survival of the nymphs (e.g., see MacCarthy, 1956; Gage and Mukerji, 1977: and Smith and Holmes, 1977).

As a result of the recent sequence of climatic conditions grasshopper populations in 1984 and 1985 exhibited increases around loci established in 1983 due to dry conditions (Grace and Johnson, 1985). Direct losses to grasshoppers were estimated to exceed $100 million in Alberta and Saskatchewan in 1984 and 1985 with even more likely lost in forage on rangeland, hayfields and pastures. (G. W. Hewitt of the USDA Rangeland Insect Laboratory estimates that in 17 western states 23% of the forage suitable for grazing livestock was destroyed by grasshoppers, causing an annual loss exceeding $400 million.)

A decline in the abundace of grasshoppers in 1986 (Figure 9 and Table 9) was mainly due to poor conditions during the main part of the breeding season (late July through early September) in 1985.

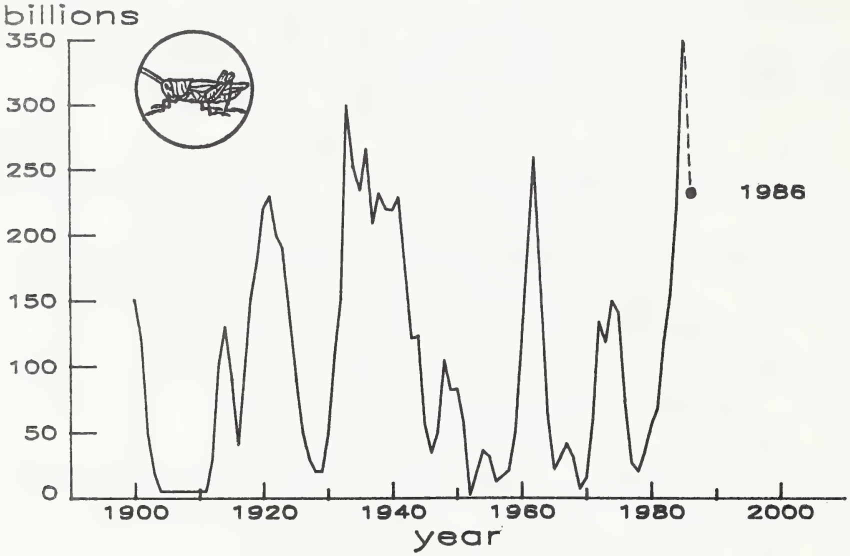

Figure 9. Abundance of grasshoppers in Alberta, 1900-1985. Data courtesy of Agriculture Canada, Lethbridge Research Station.

Table 9.

The area (x 1000 km^2) of agricultural land in Alberta and Saskatchewan infested with grasshoppers

	1984	1985	1986
Light	162	130	148
Moderate	102	97	120
Severe	65	187	120

1 km^2 = 100 ha; 1 ha = 2.47 acres

Data courtesy of Agriculture Canada (Johnson and Andrews, 1986; Mukerji and Braun, 1985). Categories of Light and Very Light have been grouped together. Similarly, the listing of Severe is a combination of Severe and Very Severe categories.

THE DIRTY THIRTIES

Whenever dry spells or droughts occur there are references and comparisons to the drought conditions and dust storms of the 1930's. However, it is difficult to compare the conditions of the 1930's and droughts of 1984 and 1985. The major problems during the thirties were caused by poor soil management, improper tillage practices, major infestations of grasshoppers and other insects, and a poor economy. With modern cultural practices, strip farming, and minimum tillage, wind erosion is less of a problem. Pest management programs today include extensive monitoring and control procedures. Government programs and crop insurance have alleviated some of the worst of the economic problems that producers faced during the thirties.

From a climatic point of view, the minimum precipitation at Lethbridge during the 1930's occurred in the 1930-31 crop year with 287 mm being recorded. The total for 1983-84 was only 213 mm. The 2 mm of precipitation recorded in Lethbridge during June 1985 was less than in any June period during the thirties. The dry years of 1930-31 and 1935-36 would probably have resulted in poor yields and crop failures even with the use of modern agricultural practices. However, when assessing the effects of drought, absolute differences in precipitation amounts can be misleading. Crop failures may occur during one year and not in another even though both years have the same total precipitation. Timing of precipitation events and their effect on soil moisture are the critical elements in assessing droughts.

Recently, Hage (1985) developed a dry-year or drought index for southern Alberta. The index is derived from averaged climatic data and from community histories that encompass most of the settled areas of southern Alberta. According to the index (Table 10), 1985 was the fourth worst drought year since 1888, the first year for which he has attempted to estimate a value. According to his index the drought of 1985 was more severe than the thirties, and the worst in 65 years.

Table 10. Drought Index

Year	Index
1910	.60
1918	.47
1919	.43
1985	.36
1930	.34
1936	.33
1922	.32
1961	.32
1984	.23

A drought index based on soil moisture measurements would, of course, be an improvement in assessing the severity of drought. Such data, however, do not exist for such extended periods.

CLIMATIC CYCLES

Owing to the variation in precipitation from one year to the next, water deficits also vary with time. Droughts occur when weather systems deviate from their usual flow patterns. The underlying reason for this is not yet understood. Unusual sea-surface temperatures and continental snow-cover conditions may have significant effects. An example of a surface pattern of a warm dry day is displayed (Figure 10) for July 17, 1984. Major features of this map are the extension into southern Alberta of the Pacific high pressure ridge, and the location of a low pressure system well to the north, just south of Great Bear Lake. This kind of pattern generally prevents moisture from entering the southern prairies.

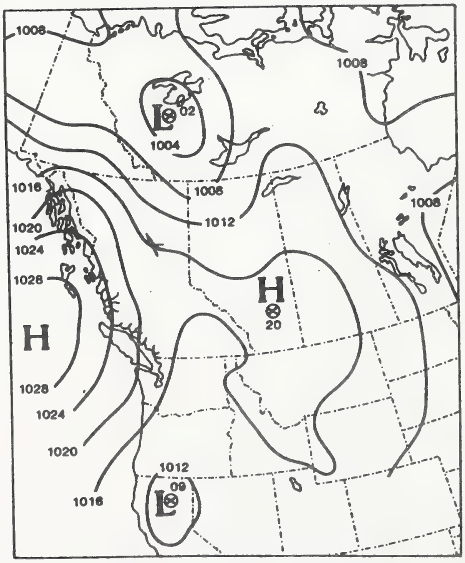

Figure 10. Surface pattern for western Canada, at 0000 hours, GMT, on July 17, 1984. Data courtesy of Atmospheric Environment Service, Environment Candada.

Accurate short-term forecast (a few hours, days) are commonplace today. However, long-term forecasting (months and years) of phenomena such as a drought for a given location is still unreliable. There have been many attempts to relate the occurrence of droughts at specific locations to climatic cycles, but unfortunately there has been only limited success to date. While some researchers have found evidence of an approximately 20-year drought cycle on the prairies (Figure 11), over 90% of the total variation in precipitation from year to year cannot be accounted for by this cycle. Indeed, the occurrence of any cycle in past weather is no guarantee that it will continue in the future.

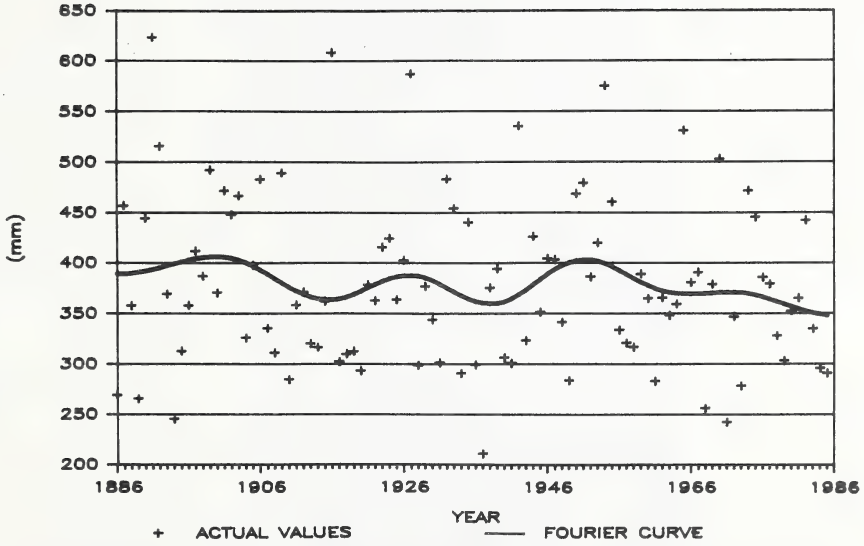

Figure 11. Annual precipitation at Swift Current with fourier curve applied to data (Ripley, 1986).

PROSPECTS FOR 1987

Accurate long-term weather forecasts are not available. However, from the indicators mentioned above, some insights into the forthcoming agricultural year are possible.

Well above average precipitation was recorded during September 1986 for much of the southern prairies. For example, southern Alberta and Saskatchewan recorded rainfall of 250 to 650% of normal (Figure 12). This rainfall replenished the depleted soil moisture reserves. Much of this moisture was locked into the soil with the freezing temperatures of November and is the basis for soil moisture reserves for spring planting in 1987. With adequate spring and summer precipitation the potential for good crops appears excellent.

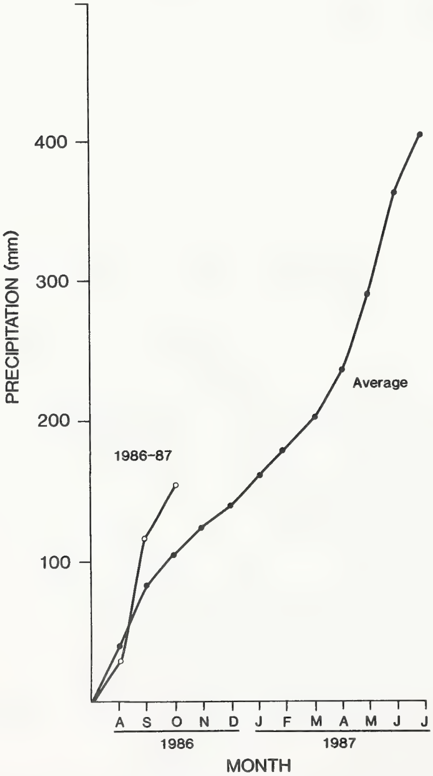

Figure 12. Accumulated precipitation recorded at the Lethbridge Research Station for the 1986-87 crop year.

The grasshopper outbreak, which has been increasing in severity since 1983, was slowed in 1986. The cool, wet weather of August and Septempber 1985 interfered with the egg-laying activities of the insects. This year, moderately warm and dry August weather allowed considerably more egg-laying than in August 1985. However, the wet September weather precluded much late-season egg-laying. The 1987 forecast indicates that the area infested has decreased slightly. The distribution pattern shows a greater variability in abundance among sites (Figure 13). The potential still exists for serious infestations for many locations in southern Alberta and Saskatchewan in 1987.

The potential for serious wind erosion of soils also still exists. Fields that are most susceptible are those that were in fallow during the 1986 growing season and had a crop failure the previous year and hence little initial crop residue.

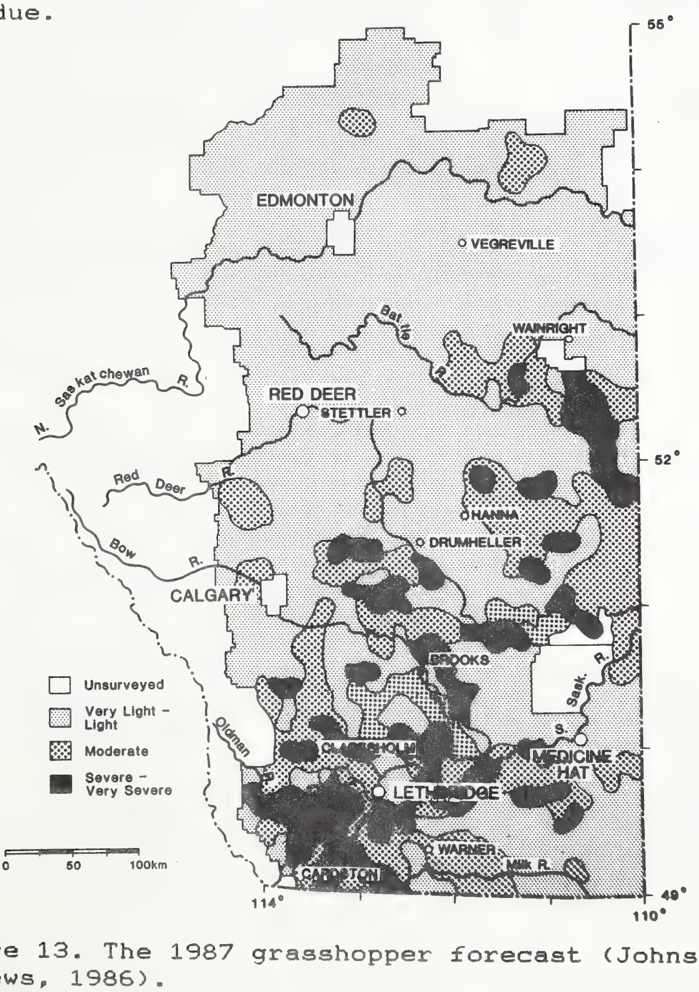
55°
EDMONTON
VEGREVILLE
Battle R.
WAINRIGHT
N. Saskatchewan R.
RED DEER
STETTLER
52°
Red Deer R.
HANNA
DRUMHELLER
Bow R.
CALGARY
BROOKS
S. Sask. R.
MEDICINE HAT
Oldman R.
CLARESHOLM
LETHBRIDGE
WARNER
Milk R.
CARDSTON
Unsurveyed
Very Light - Light
Moderate
Severe - Very Severe
0
50
100km
114°
110°
49°

Figure 13. The 1987 grasshopper forecast (Johnson and Andrews, 1986).

SUMMARY

Many of the seemingly unrelated events of irrigation supply problems, grasshopper infestations, dryland crop failures, wet harvest conditions, and increased soil erosion of 1984, 1985, and 1986 are related to the historical climatic events which began during 1983. Even before the 1984 growing season began, analysis of precipitation data, over winter soil moisture measurements, grasshopper survey information, snowpack surveys and river flow data indicated that the potential for serious problems existed for agriculture in the southern prairies. The events of previous summers suggest that the potential still exists for continued grasshopper and soil erosion problems. Continued reporting of environmental and agricultural monitoring programs allows producers to make more informed cropping and management decisions.

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ON-FARM PRODUCTION AND MANAGEMENT IMPLICATIONS

Jack Gorr
Producer, Three Hills, Alberta

Thank you Mr. Chairman, Ladies and Gentlemen for inviting me to share this podium with such a distinguished list of speakers, as well as address your 5th Annual Conference.

The theme of your conference "Moisture Management in Crop Production", is one which all of us especially those of us in farming, can relate to and only last year was of paramount concern to many of us. Any technologies, or strategies derived either through experimentation or experience that can minimize the impact of drought will provide enormous financial and stabilizing benefits for both farmers and the general economy.

In addressing the "Topic on Farm Production Implications", and keeping within this theme and objectives of the conference and guidelines issued to me, I have assumed that my particular role is to provide a farmer's view on how various factors such as costs and returns are impacted by moisture management and conservation.

Moisture management and conservation to farmers implies cropping the land more frequently rather than fallowing, even though fallowing has long been used as a moisture management strategy. Continuous cropping, however, does have fairly extensive cost, revenue and institutional implications at the farm level. In order to illustrate these I have set out in a series of tables with various operational, cost and revenue factors which are dependence on the acres cropped and those which are dependent on the acres fallowed. Unfortunately, some of the factors listed differ according to whether the land to be cropped, had been previous cropped (stubble) or had been in fallow. Consequently these 3 categories have to be compared. Before going into the comparison I would like to point out that it is not my intention of "proving" whether continuous cropped is more profitable than crop-fallow rotations, but simply to provide a system whereby one can identify what is happening as one takes land out of fallow and crops it more frequently. In fact I would have preferred to avoid using figures altogether, however, I feel it is important to provide you with some appreciation for the relative size of the numbers involved. Consequently, in the tables to follow, I have used only ranges and aggregate figures.

ON-FARM CASH COST IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

In order to compare the cash costs of growing crops on stubble to those of growing crops on fallow we have to first identify those cash costs which are dependent on fallowing.

In examining Column III of Table I we see only one item, summer tillage, which is dependent on fallowing. Herbicide usage and application is footnoted and may be used in lieu of tillage, depending on which of the two is the lower cost. Regardless of which is used these are real costs and have to be charged against the crop grown on fallow. Transferring these costs (TFC) to Column II enables us to directly compare Column I and II.

As one can see many of the operations and items listed are dependent on both the crops grown on stubble and those grown on fallow. Consequently these items will be the same for both cropping systems and can be dispelled of with little or no comment. This is not to say that they are not real costs but only that they are equal for both cropping systems. Possible differences between the two systems occurs in the area of seed bed preparation, amount to nitrogen fertilizer that may have to be applied, its application, other operations which may result in specific operation to breakdown the straw on continuous operations and the cost of fallowing.

ON-FARM CAPITAL INVESTMENT IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

Using the same methodology as used in Table I but trying to compare the capital investment requirements of the two systems one has to identify those capital items which are associated with the fallowing activity.

As one can see from Column III Table II many of the capital items listed are not applicable to fallowing. Several of the capital items are complementary (C) which signifies the item is required but can use the same capital item as is needed for the cropping operation. The capital items of farm power (tractors), spraying and herbicide equipment are items which are needed for the cropping systems but are available during the summer and can be used for fallowing. Additional investment in tillage equipment may be required for the fallowing operation especially in areas where blade cultivators and rod weeders are the normal fallow implements. Other areas which do not use specialized fallow equipment may not find it necessary to add additional implements beyond that needed for fall tillage and seed bed preparation under continuous cropping operations. In any case the extra investment that is required and would be relatively insignificant in comparison to the overall investment in machinery.

In comparing the capital requirement of Column I and II once again we can dispel the majority of the items as they are required for both systems. Some difference may occur in the investment required for herbicide and fertilizer applicating equipment. Crops grown on fallow, due to their lower trash levels, usually do not require granular herbicide equipment. Also fallow normally has higher levels of nitrogen and consequently may not need additional nitrogen application equipment. Continuous cropping systems on the other hand normally do require large applications of nitrogen. Also, because of the greater variability of yield and other impacts associated with adverse weather, continuous cropping systems may require a greater variety of crop handling equipment, such as double swath attachments, swath turners, straight combine headers, drying equipment, etc.

Table III is designed to identify the impact continuous cropping vs crop-fallow operations have on labour and storage requirements. In addition, a further complication, that of competitive operations and its possible impact on labour and labour's substitute (capital) is also included in this table. For analytical purposes the labour requirements have been divided into 4 distinct periods and are referred to as the spring, summer, fall, and winter periods. However, one should interpret these to correspond to the seed bed preparation and planting operations, spraying and summer tillage operations, harvesting and post harvest operations and the freeze up period.

In comparing Column I to II we see that for at least two periods the labour requirement is dependent on the number of acres cropped. However, the question that has to be answered is whether the requirements are the same or does the land's history (stubble or fallow) effect the per acre requirement for labour. In referring back to Table I, and noting the different operations required for crops grown on fallow and those on stubble, our attention is drawn to four possible differences. Crops grown on fallow may not require the same time in the spring to prepare the seed bed as those grown on stubble resulting in lower labour requirements in the spring period. Likewise separate fertilizer and granular herbicide applications on fallow may not be necessary, freeing up time in the spring and/or fall periods. Post harvest land preparation also is not necessary if the land is to be fallowed. Consequently more time is available for the harvesting operation.

The financial impact of having to perform more operations during the spring and fall periods on continuous operations is difficult to measure for two reasons. Firstly, surplus family labour may be available and secondly, machinery can be substituted for all or part of the extra labour required. In either case continuous cropping systems require more labour and/or more machinery relative to the same acreage when cropped on fallow. In other words, both the acreage cropped and the percentage of the land cropped affect the requirement for labour and machinery. The figures given in Table III indicate labour may have to be enhanced as much as 50% or alternatively machinery as much as 30% or some combination of the two.

Grain storage requirements on a per cropped acre basis are normally less for crops grown on stubble due to its lower yield relative to crops on fallow. However, some modification of this may be necessary during periods of restricted delivery of Board grains. Present quota policy gives some consideration to cropped acres but still provides a basis in favour of crop-fallow rotations. Consequently larger per acre crop carry overs on continuously cropped land may negate part of the savings from the lower per acre production.

FINANCIAL IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

Table IV provides a summary of the information outlined in Tables I, II and III and provides a range of the accumulated costs for the continuous cropping and crop fallow systems of \$108 - \$195 and \$94 - \$209 respectively. This does not include the \$18 - \$20 per crop acre that may be necessary due to competitive operations that occur under continuous cropping systems. Taking these costs into consideration brings the per crop acre range of costs for the continuous crop system of \$128 - \$213.

In order to get an appreciation for the magnitude of the on farm financial implications of changing to continuous cropping the various cost categories discussed have been applied to a 1000 acre farm and contained in Table IV.

ON FARM REVENUE IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

No discussion on cropping systems would be complete without some mention of the revenue sector. Table V lists some of the factors affecting revenue and as with the other tables comparisons are made between crops grown on stubble, crops grown on fallow, and fallow itself.

Yield experiences on stubble vary both between years and between soil zones, as well as with management practices. Yield data seems to indicate that for a major part of the prairies one can expect crops grown on stubble to average 70%-80% of the yield of crops grown on fallow. Variability of yield however is considerably greater with crops grown on stubble.

Personally I have experienced years when crops grown on stubble yield between 40%-110% of those grown on fallow. Crop insurance coverage of stubble crops is set at 70% of fallow crops.

Revenue from the sale of crops may or may not be directly related to yields. Quotas or delivery rights are established by the Canadian Wheat Board and determines how much can be sold. In recent years the CWB has given some consideration to acres cropped rather than just cultivated acreage. This recognition allows one to gross up his eligible acres by 30% for the acreage grown on stubble. This gives equitable delivery treatment if stubble crops only yield 65% of fallow crops.

Various types of rental agreements likewise impact on the different cropping systems. In share cropping agreements tenants give a percentage of the total production to the landlord. Costs on the other hand are born by the tenant and are generally higher on a per unit of production under continuous cropping.

Cash rent like taxes are not dependent cropping intensity and are more neutral with regard to cropping systems.

The indifference data shown in Table V is provided to try to tie together both the revenue and cost data for both the continuous and crop fallow rotations. The data given is expressed in the more generalized form of percentage (%), and uses 100 as an index for crops grown on fallow. It also assumes that the cost to crop an acre of fallow and an acre of stubble are the same. This may, or may not be the case as outlined in the preceding tables. For interpretive simplicity it might be better to think of this as for each $100 of revenue. In which case the relative revenue from stubble yields would be $60 to $90 using yields as a percentage of fallow of 60% to 90% respectively. Using Column I a cost of 20% of the base $100) would amount $20 and result in a return of $100 - $20 or $80 for each acre cropped on a crop fallow rotation. Assuming the 60% relative yield of stubble in Columns I and similar costs to crop an acre of stubble as compared to fallowing the resulting return would be (60% x 100) or $60 less the $20 costs or $40 on each acre cropped. However as there would be double the acres sown in the latter case the total return would be identical for the two rotations. Applying this interpretation to Column IV and using a relative yields of 90% for crops on stubble would imply that costs of 80% of the base would give equal return to the two rotations.

i.e., (80% x $100 (base)) = $80 cost
Return on fallow $100 (base) - $80 = $20 x 50% per cropped acre
Return on stubble 90% x $100 (base) = $90 - $80 = $10 per cropped acre

The 70% relative yield of stubble to fallow crops as used by the Alberta Hail and Crop Insurance Corporation would indicate that one's costs could not exceed 40% of the expected revenue from the fallow crop in order for the stubble crop to be as profitable as that grown on fallow.

Before closing I would like to make a few brief summary comments.

The relative per acre cash costs of the two cropping systems appear to be almost identical. The crop grown on fallow has an extra cost for two to four net tillage operations whereas the crop on stubble has extra costs for applying granular herbicide and fertilizer as well as the possibility of extra nitrogen. Any significant differences in the per crop acre cash costs will depend on the relative level of nitrogen required by the two cropping systems.

Combining both the annual machine investment costs and the labour requirement would indicate either or both could be higher on a per crop acre basis for the continuous cropping system. This is caused by having to do more operations in particular time periods, mainly spring and fall. Storage costs may be slightly less under continuous cropping systems when calculated on a per crop acre basis. This however may not be the case under limited delivery situations where quotas present a bias against continuous cropping systems.

Revenue from the two cropping systems depends on both the relative yield and the eligible quota acreage. Present quota policy allowing one to gross up his eligible quota acreage by 30% for crops grown on stubble in effect assumes stubble yields of 65% of fallow.

Rental agreements, particularly those of a crop share basis raise rents for those tenants considering or practicing continuous cropping.

Risk implications on stubble are greater due to the greater variability of yields. Crop insurance cover for stubble crops is based on 70% of fallow yields.

Using this figure and applying it to where each cropping system would have similar net farm income would indicate total costs could not exceed 40% of the expected gross revenue from crops grown on fallow.

Respectfully,
Jack Gorr

Table 1
ON-FARM COST IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

Description		Per Crop Acre on Stubble	Per Crop Acre on Fallow	Per Fallow Acre
Seedbed Preparation		D	P	NA
Seeding Operation		D	D	NA
Seed and Treatment		D	D	NA
Fertilizer:	Phosphorus	D	D	NA
	Nitrogen	D	0-100%	NA
Fertilizer Application		D	P	NA
Herbicides:	Broadleaf	D	D	1/
	Grassy Weeds	D	D	NA
Crop Insurance		D	D	NA
Swathing		D	D	NA
Combining		D	D	NA
Post Harvest Tillage		D	NA	NA
Summer Tillage		NA	NA	D
Other Operations		?	P?	NA
Transfer of Fallow Costs		NA	TFC	
Cash Cost per Crop Acre		$60-80	$55-85	
Interest on Operating Capital		$5-10	$5-10	

D - Dependent
P - Partially Dependent
NA - Not Applicable
? - Questionable: depends on conditions
1/ - Used in Lieu of Tillage

Table 2
ON-FARM CAPITAL IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

Description	Per Crop Acre on Stubble	Per Crop Acre on Fallow	Per Fallow Acre
Machinery Requirements:			
- Power	D	D	C
- Tillage	D	D	P
- Planting	D	D	NA
- Spraying	D	D	C
- Swathing	D	D	NA
- Combining	D	D	NA
- Truck	D	D	NA
- Herb. Applic'rs	D	P	C
- Fert. Applic'rs	D	P	NA
- Other Equipment	D2/	P	NA
Machinery Investment Per Acre	$200-300	$150-300	$0-25 ?
Annual Machine	$40--60	$30--60	$0--5 ?

D - Dependent
P - Partially Dependent
NA - Not Applicable
C - Complementary
? - Questionable: depends on conditions
2/ - Greater Variability of Yield May Cause Extra Machinery

Table 3
ON-FARM LABOUR AND STORAGE IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

Description	Per Crop Acre on Stubble	Per Crop Acre on Fallow	Per Fallow Acre
Labour Requirements:			
- Spring	D	D	C or NA
- Summer	C or D	C or D	C or ?
- Fall	D	D	C or NA
- Winter	NA	NA	NA
Total Labour	$0-40	$0-38	$0-5
Competitive Operations:			
Labour Enhancement	50%-0%	NA	NA
Labour Enhancement per Acre	$20-0	NA	NA
Machinery Enhancement	0%-30%	NA	NA
Machinery Enhancement per Acre	$0-18	NA	NA
Machinery Storage	D	D	C or NA
Grain Storage	40%-110%	D	NA
Total Build. Invest. per Acre	$20-40	$30-50	C or NA
Annual Storage Cost per Acre	$3-5	$4-6	

D - Dependent
P - Partially Dependent
NA - Not Applicable
C - Complementary
? - Questionable: depends on conditions

Table 4
FINANCIAL IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

Description	Per Crop Acre on Stubble	Per Crop Acre on Fallow	Per Fallow Acre
Cash Cost per Crop Acre	$60-80	$55-85	
Interest on Operating Capital	$5-10	$5-10	
Annual Machine	$40-60	$30-60	$0--5
Annual Storage Cost per Acre	$3--5	$4--6	
		TFC	TFC
Accumulted Costs per Crop Acre	$108-195	$94-204	
Labour Enhancement per Acre	$20--0	NA	NA
Machinery Enhancement per Acre	$0-18	NA	NA
1000 Acre Farm	$60000--80000	$27500--42500	
Cash Costs	$108000-195000	$47000-102000	
Accum. Costs	$200000-300000	$75000-162500	
Stor. Bldg. Inv.	$200000--40000	$15000--25000	
Lab. &/or Mach. Enhancement	$20000-18000	NA	
Land	Same	Same	

Table 5
ON-FARM REVENUE IMPLICATIONS OF CONTINUOUS CROPPING SYSTEMS

Description	Per Crop Acre on Stubble	Per Crop Acre on Fallow	Per Fallow Acre
Yield	70% (40%-110%)/3	100%	NA
Revenue:			
Price x Quota	1.3x	1x	1x
Crop Share	D	D	NA
Crop & Expense Share	D	D	?
Cash Rent	NA	NA	NA
Taxes	NA	NA	NA

Description	Indifference Table			
Crop/Fallow Yld/4	100	100	100	100
Stubble Yield/5	60	70	80	90
Costs % of F.Yd/6	20	40	60	80

/3 Percent of Fallow Yields
/4 Fallow Yield Index
/5 Stubble as a Percent of Fallow
/6 Costs as a Percent of Fallow Index

Plenary Session II

EMERGING PRACTICES TO MAXIMIZE CROP PRODUCTION UNDER LIMITED MOISTURE CONDITIONS

CHAIRMAN, S. KRAMER, ASSISTANT DEPUTY MINISTER,
SASKATCHEWAN AGRICULTURE

ABSTRACT

Tillage and Cropping Systems

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In the semi-arid regions of the prairies water is the most limiting factor for crop production. Potential evaporation is often three to four times the annual precipitation, therefore, severe moisture deficits develop unless there is sufficient moisture stored in the root zone prior to planting. Often one-half of the 250 mm of water required to produce a 2 t/ha cereal crop comes from soil moisture stored before planting. We have little or no control overgrowing season precipitation, but we can affect our soil moisture conservation and water use efficiency by adopting more effective tillage and cropping practices.

Numerous studies on the prairies have shown that the 20-month conservation efficiency for summerfallow ranges from less than 10 percent in the Black and Grey soil zones to 25 percent in the Brown soil zone. Chemical summerfallow can improve the soil moisture conservation and eliminate the risk of soil erosion, but the benefits are often not sufficient to offset the cost of the most effective herbicides. Minimum tillage systems involving some substitution of economical herbicides for tillage after harvest and in the spring of the fallow year have proven to be quite effective and a practical alternative to traditional summerfallow practices. Shallow cultivation in July and August can be quite effective in minimizing evaporative losses during prolonged dry periods. Since 80 to 90 percent of the precipitation that occurs between June and August of the fallow season is lost through evapotranspiration, producers should consider growing an annual legume or other green manure crops to make some productive use of this precipitation that is normally lost.

Obviously, continuous cropping when possible is the most effective practice to maximize water use efficiency and maintain soil productivity. When soil moisture reserves are adequate in the spring, summerfallow cannot be justified in most situations. Crop rotations involving winter wheat have proven to be very effective in making most effective use of soil moisture and seasonal precipitation. In many areas, snow management practices could improve our moisture conservation efficiency over winter and reduce the risks associated with recropping in the Brown and Dark Brown soil zones. Zero tillage systems have the greatest potential application in recropping rotations (particularly with winter wheat) where herbicide requirements are low and perennial weeds are not a problem. Timely and effective application of herbicides and fertilizers are vital to maximizing the water use efficiency of more intensive crop management systems.

MOISTURE MANAGEMENT WITH TILLAGE AND CROPPING SYSTEMS

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In the semi-arid regions of the prairies water is the most limiting factor for crop production. Potential evaporation is often three to four times the annual precipitation, therefore, severe moisture deficits develop unless there is sufficient moisture stored in the root zone prior to planting. Often one-half of the 250 mm of water required to produce a 2 t/ha cereal crop comes from soil moisture stored before planting. We have little or no control over growing season precipitation, but we can affect our soil moisture conservation and water use efficiency by adopting more effective tillage and cropping practices. Tillage or the lack of tillage can affect runoff, infiltration, evaporation, and water use by weeds; all of which are important factors in the conservation of water. Crop rotations, fertilizer inputs, and herbicide applications can also have a significant affect on water use efficiency and optimizing crop production.

Summerfallow

Summerfallow continues to be practiced on nearly 9 million hectares in the prairies despite widespread controversy regarding the practice. Advocates of summerfallow have emphasized the benefits of moisture conservation, weed and disease control, and crop yield stability whereas critics have emphasized the problems of moisture storage inefficiencies, wind- and water-erosion, soil salinization, and long-term losses of soil fertility associated with fallow.

Numerous long-term studies on the prairies have shown that the 20-month conservation efficiency for fallow ranges from less than 10% in the Black and Grey soil zones to 25% in the Brown soil zone. Moisture conservation generally increases at a decreasing rate during the 20-month fallow cycle. Typical conservation efficiency during the first winter period (October-April) may be 45% and is inversely related to the soil water status prior to freezing. Conservation efficiency during the summer season (May-September) is typically between 10 and 15% of the precipitation received during that period. Evaporation rates are considered to be too high during the summer for conventional or minimum tillage practices to conserve significant amounts of precipitation. Also, this low storage during the summer portion of the fallow cycle is in part related to the amount of water stored over the first winter period. The conservation efficiency during the second winter period (October-April) may typically be in the range of 20% but again is highly dependent on the antecedent moisture status. Overall, we see that 80-90% of the moisture conserved during the 20-month fallow period is conserved during the two fall-winter-spring seasons. Furthermore, if we could conserve an additional 50-60 mm of precipitation during the first winter period (October-April) by improving the conservation efficiency from 45 to 74% in the Dark Brown soil zone, then as much moisture would be conserved as during the remaining 12-month period. In this regard, special residue management practices and snow trapping may offer considerable potential for improving overwinter moisture conservation. Since long-term research has shown that on summerfallow we conserve very little if any of the precipitation that occurs between May and August, a good case could be made for growing an annual legume crop as a green manure instead of summerfallow. This would obviously make more effective use of the seasonal precipitation that is normally lost and improve soil quality.

In a summerfallow system the type of tillage practice has a surprisingly small effect on the overall efficiency of moisture conservation. Numerous studies have shown that the type and number of tillage operations significantly affect the conservation of crop residues (Anderson, 1961,1964,1971). The benefits of maintaining upright crop residue to prevent soil erosion and improve soil moisture conservation are also well documented (Greb et al., 1967; Masse and Cary, 1978). However, several studies on the prairies have shown that at least three tillage operations are required for weed control on fallow land, and that even sweep tillage results in very little upright stubble after three tillage operations (Dew, 1968; Molberg et al., 1967; Anderson, 1968,1971).

Barriers to retain liquid and solid water when it falls can be established with and without tillage. The rates of runoff of water can be reduced by increasing the random roughness of the soil surface with tillage. Runoff can occur during the non-growing season from precipitation events and/or from snowmelt water in some years on the prairies. But, rainfall events occur infrequently during the non-growing season and the chances are very small of receiving large intensive rains to cause runoff. The benefits of tillage to improve water intake, therefore, are less important than the reduction or loss of residues to trap snow resulting from tillage. In terms of moisture conservation, the primary benefit of tillage in a fallow system is weed control. A thorough review on the subject of fall tillage failed to reveal any study where the practice resulted in significant yield increases from subsequent crops (Lal and Steppuhn, 1980). But, post-harvest tillage that leaves stubble in the most erect position is the best alternative to no tillage for maximizing storage efficiency.

Soil water storage on a given soil may be increased in the presence of surface barriers when because of reduced evaporation rate, a differential in soil water content exists at or near the surface when the next precipitation event occurs (Army et al., 1961). However, while surface barriers reduce evaporation rate from the upper part of the soil profile, they do not necessarily reduce the total amount of water loss (Bond and Willis, 1969). Given sufficient time without addition of water, evaporation losses are equal in amount, irrespective of surface barriers commonly used in the field. During the summers of 1985 and 1986 at Lethbridge it was noted that chemical summerfallow lost 25 to 50 mm more moisture than cultivated fallow during prolonged periods without precipitation. This occurred because the chemical fallow had more moisture to lose and little protective crop residue cover to reduce evaporation. The cultivated fallows had a dry layer of soil which insulated the subsurface moisture from evaporation.

Chemical fallow systems involve the substitution of contact or pre-emergence weed control herbicides for two or more tillage operations. Previous work on the prairies has shown that chemical fallowing increased crop residue conservation, provided greater erosion protection, conserved as much moisture, and resulted in equivalent crop yields compared to conventional cultivated fallows (Molberg and Hay, 1968; Anderson, 1971,1975). More recent research at Lethbridge has indicated that chemical fallows conserved more moisture and resulted in greater yields than conventionally tilled fallows (Lindwall and Anderson, 1981). But, there was some evidence that the additional moisture conserved with chemical fallow was not being fully utilized, possibly due to less than optimum NO_3-N levels. Also, the high cost of repeated applications of herbicides required to maintain optimum weed control would indicate that the chemical fallowing is not currently economical. Furthermore, there is some concern that in many regions on soils with limited water holding capacity, that chemical fallow may, in fact, aggravate soil salinity problems because of the potential for greater quantities of soil water percolating through the soil profile in wet years. The greatest application for chemical fallow may be in the Brown soil zone where the risk of soil erosion is greatest and the potential benefits of increased moisture conservation can be translated into increased yields. But realistically we can expect chemical summerfallow to conserve only about 25 mm more moisture than our most efficiently cultivated summerfallow.

Recropping

Research has shown that if there is at least 80 mm of available soil moisture on stubble land in the spring then the prospects for successful recropping are high. But considerable soil moisture data seem to indicate that much of the 9 million hectares that are fallowed each year have at least 80 mm of available moisture in the root zone by planting time in the spring (deJong and Steppuhn, 1978; Kirkland and Keys, 1980). Furthermore, the first winter period by the maintenance of stubble or by snow management practices then summerfallow could not be justified on the basis of moisture conservation.

The obvious question at this point is "why are producers so unwilling to recrop stubble land?" There is little doubt that the traditional summerfallow system has provided the producer with greater income stability than that associated with a recropping system. A recropping system involves much more management ability than a summerfallow system. A recropping system requires greater inputs of fertilizer and herbicides, and the effective application of these chemicals may involve several timely tillage operations. If there is any residue left on the surface the farmers will normally bury this with additional preseeding tillage or with the planting operation itself. The result of all this preseeding tillage is often a dry, loose seedbed and subsequently a poor crop stand.

Herein lies much of the problem associated with producers' unwillingness to recrop. There may have been the necessary 80 mm of available soil moisture in the root zone prior to the farmer getting on the land, but several improper or unnecessary tillage operations may result in a 15-25 mm soil moisture loss. The type of tillage used for seedbed preparation on recrop or stubble ground can greatly influence crop yields while that for seedbed preparation on fallow appears to have little influence on yields (Lund, 1980). Tillage plays a major role in affecting efficient use of water in those cases where magnitude of yield is affected by plant population. Seeding equipment must be compatible with the tillage system so as to establish a seedling population that will effectively use the larger soil water supply that may be associated with the tillage practice (Bauer, 1980).

Rate of water loss by evaporation from soil, apart from surface barriers, is affected by soil porosity and aggregate size, two soil properties that are altered by tillage. Hanks (1958) showed water vapor diffusion rates to be about 23% higher at 58% porosity than at 43% porosity of a silt loam soil at the same water content. Also, increasing the thickness of dry soil from 6 to 36 mm reduced the vapor flow rate about 5.5-fold at both porosities. Several other studies have also demonstrated the importance of aggregate size at the soil surface in relation to evaporation rates (Wenhardt, 1962; Lyles and Woodruff, 1962; Papendick et al., 1973).

Also important in maintaining adequate soil water in the seedbed zone is establishment of capillary continuity to deeper soil layers so as to balance water losses by evaporation. Under good soil moisture conditions (near field capacity) very little packing of the soil surface above the seed is necessary and often results in suppressed emergence of crops due to poor aeration or high mechanical impedance. However, with a drier surface soil but capillary moisture below the seed, surface pressures of at least 70 kPa result in the best emergence. Packing at seed level and covering with loose soil often enhances emergence and reduces surface crusting. Compactive effort generally reduces the effects of granule size on drying rates. Straw mulches that have a high resistance to diffusion generally erase any effect of granule size on drying rate. Obviously, the best management practice for conserving soil moisture in the seedbed zone is very dependent on the existing soil moisture conditions and the extent of crop residue cover.

A long-term study recently completed in west-central Saskatchewan compared several snow management practices and cropping sequences with respect to moisture conservation and utilization (Kirkland and Keys, 1980). Standing stubble in a continuous crop rotation was the most effective practice, conserving 50-60 mm more annual moisture than bare fallow. Continuous wheat produced higher grain yields and used the available soil moisture more efficiently to produce more per year than either fallow-wheat or the fallow-wheat-wheat rotations. Successful recropping or continuous cropping systems will undoubtedly make more efficient use of the limited and highly variable precipitation that occurs in the semi-arid regions of the prairies. Substantial reductions in the area devoted to summerfallow will reduce the problems of dryland salinity and soil erosion associated with summerfallow. However, the research effort devoted to improving the water use efficiency of recropping must be balanced with that devoted to dealing with weed control, fertilization, or other problems associated with recropping.

Zero-tillage

Zero-tillage or no-till is a system in which a crop is planted (with minimum soil disturbance) directly into the untilled stubble from the previous crop using appropriate herbicides for weed control. The most important advantages of no-till are reduced water and wind erosion, lower energy requirements, and greater moisture conservation. No-till or direct drilling has been a commercial practice for some crops in many parts of the world for many years but the practice has gained little acceptance in the semi-arid regions of the prairies. The importance of crop residue distribution, timely weed control, efficient fertilizer application, and, perhaps, specialized seeding equipment for zero tillage places a great deal of emphasis on the farmer's management skills. The high cost of the most suitable herbicides for weed control compared to the cost of cultivation is considered by many producers to be the most limiting factor in the adoption of zero tillage.

No-till has been most successful for corn-meadow rotations in the humid regions of southeastern U.S. However, in the Corn Belt and many parts of the Great Plains region no-till has resuled in significantly lower yields than those from conventionally tilled systems. The most common reasons for the lower yields with no-till have been poor seed placement, inadequate weed control, and depressed plant growth due to poor aeration, excessive soil strength or reduced soil temperatures. The development of better planting equipment and more suitable herbicides will help overcome many of the problems associated with no-till cropping systems, but we need a better understanding of the soil micro-environment under a no-till system (as well as different tillage systems). Limited research and considerable speculation would indicate that the soil moisture regime associated with no-till can have important implications on such aspects as nutrient mineralization, fertilizer placement, residue phytotoxicity, weed control, and crop diseases; but these relationships are not well understood.

Considerable research has been done in the U.K. to identify the soils that may be suitable for no-till in terms of their texture, porosity, infiltration and drainage characteristics (Cannell et al., 1979). They observed that the soil aggregate stability and adequate drainage were most important for successful no-till production. They also found that the benefits of pore space continuity and improved infiltration associated with no-till may not be achieved for many years depending on how much damage was inflicted on the soil structure by the previous tillage system. On coarse textured soils in Western Australia it was demonstrated that the shallow surface layer of soil that is directly deformed by tillage can play a significant role in the behavior of soil water, not only within that zone, but through its influence upon those deeper portions of the profile that accommodate plant roots (Hamblin and Tennant, 1981). They found that the pore geometry on zero-tilled soils resulted in the most evaporation and total soil moisture loss compared to other tillage systems. They concluded that sandy textured soils with relatively poor organic matter status (1.25%) were not well suited for no-till crop production. However, these studies in the U.K. and Australia were conducted under essentially residue-free conditions. Similar studies should be conducted on the prairies to determine effects of different quantities of crop residue on the soil water dynamics of different tillage systems.

A recent study at Beaverlodge on a clay-loam soil illustrated that a shallow cultivation in the early spring resulted in more soil moisture conservation than that with no-tillage (Darwent and Bailey, 1981). They also found that tillage treatment had little effect on soil temperature, but the study was conducted on fallowed land with little or no crop residue. Some work in Manitoba demonstrated that lower soil temperatures under no-till would not be a limiting factor for crop production (Gauer et al., 1980). They found soil moisture conservation was greatest with no-till on clay soils with or without crop residue. The importance of crop residue distribution, timely weed control, efficient fertilizer application, and, perhaps, specialized seeding equipment for zero tillage places a great deal of emphasis on the farmer's management skills. No-till has the greatest potential application in a recropping system where herbicide requirements are low compared to a chemical summerfallow system. Improved moisture conservation with no-till reduces the risk associated with recropping by increasing the yield potential.

The high cost of repeated herbicide applications for no-till chemical fallow has prevented the practice from becoming economical for the production of spring cereals, however, no-till winter wheat production is undoubtedly the best crop in no-till rotations for southeastern Alberta and southwestern Saskatchewan. Winter wheat makes more efficient use of soil moisture, competes with weeds better, and usually yields about 20% more than spring wheat. At Lethbridge, average yields of winter wheat grown on stubble have been equal to or greater than yields of spring wheat on fallow. But, continuously cropped winter wheat will often result in severe infestations of downy brome which forces the producer to include other crops or summerfallow in the rotation.

Several years of data collected at six locations in southern Alberta (Farming for the Future Project) demonstrated that no-till was technically feasible on a wide range of soil types, but the benefits of improved soil and water conservation were not sufficient to offset the higher costs of chemical weed control in comparison to conventional tillage practices. In no-till chemical fallow rotations the total weed control costs were about $100/ha more than that for conventional tillage. But in no-till continuous cropping rotations the total costs for weed control were only $19/ha more than they were for conventionally tilled recropping rotations. Obviously, the potential application of no-till crop production is greatest in recropping rotations provided the benefits are sufficient to offset the higher costs of chemical weed control. If perennial weeds are not a problem, the cost of chemical control of most annual grassy and broadleaf weeds is becoming very competitive with that of mechanical weed control. However, long-term studies have shown that perennial grassy weeds and broadleaf weeds such as Canada thistle and dandelion are much more prevalent in no-till continuous cropping rotations.

Research to date would indicate that rotating crops reduces particular weed problems but requires greater management skills. One of the most successfull rotations for no-till has been canola-winter wheat. The crop residue from canola poses minimal seeding problems with many conventional seed drills and usually little or no herbicide is required prior to seeding winter wheat because of the residue weed control provided from using Treflan in the canola crop. Other successful rotations have been winter wheat-barley-fallow or winter wheat-winter wheat-fallow, but the large quantity of crop residue produced when winter wheat is grown on summerfallow may often cause seeding problems unless it is chopped and spread uniformly. No-till seeding of crops such as canola, flax, or lentils is still difficult because suitable post-emergent herbicides are not yet available that will selectively control problem broadleaf weeds in these crops. Furthermore, one must be very cautious about using residual type herbicides such as Glean in wheat rotations for a few years and then deciding to plant an oilseed crop. The use of residual type herbicides often reduces a producer's options with respect to using crop rotations.

There is an increasing amount of evidence to suggest that producers must consider rotating their tillage systems as well as their crops to increase soil productivity and reduce the risk of increased weed, disease, and insect problems. There should be greater emphasis on optimum economic yields rather than maximum yields. New herbicide developments in recent years such as Glean, Poast, Fusilade, etc., have made it much easier to consider different and more intensive cropping rotations that do not require the soil incorporated herbicides. Most of the major chemical companies are recognizing the importance of soil conservation and for that reason are emphasizing the development of pesticides that require little or no soil incorporation. There is still much research that has to be done with respect to herbicide application techniques and the fate of pesticide residues in no-till systems. There appears to be some potential for low volume application techniques as well as better systems for controlling droplet size. Many of the new herbicides are applied at very low rates of 20 to 30 grams of active ingredient per hectare which requires careful mixing and precise application techniques. Sprayer technology is improving but producers must be provided with good up-to-date information regarding some of the new sprayers or new spraying techniques that are being promoted. Research and extension workers must work more closely in educating the producers about the wide range of sprayer and herbicide options that are now available.

The trend towards minimum tillage systems places much more emphasis on crop residue management and how crop residue affects herbicide adsorption, movement, persistence, and efficacy. Similarly, minimum tillage systems will likely affect weed seed distribution, viability, and dormancy differently than conventional tillage systems. Additional research is necessary to address some of these concerns. In any case, weeds are best controlled in any agroecosystem through the integration of plant competition strategies, crop and herbicide rotations, and mechanical methods. Possibly the most important benefit of the limited acceptance of no-till systems is the increased awareness by everyone of the apparent need for traditional cultivation practices. There is considerable evidence that producers are reducing the number of cultivations on their land and avoiding unnecessary "recreational" tillage. Minimum tillage systems have achieved widespread acceptance throughout the world but no-till systems are going through many growing pains that will only be overcome as we get more familiar with these systems and their potential applications on the prairies.

Summary and Conclusions

Many management practices in the semi-arid regions of the prairies have water conservation as their top priority. Soil water reserves and anticipated precipitation determine the intensity and magnitude of most other inputs into the production system. Since seasonal rainfall is normally insufficient for an economic production level, maximizing storage of non-growing season precipitation is imperative. The conservation of water is difficult because of the frequency of occurrence and the amount involved during a given precipitation event, and problems involved in keeping it where it falls, especially snow. Most of our annual precipitation events produce less than 10 mm of water in a 24-hour period and events of this magnitude supply nearly one-half of our average annual precipitation. These small amounts of precipitation falling on dry soil are most subject to evaporation loss and any practices that would reduce evaporation rates prior to subsequent precipitation events would help conserve soil moisture.

Retaining snow where it falls improves the potential for water conservation. Maintaining crop residues in an upright position or other practices to trap snow and reduce snowmelt runoff have often improved the overwinter conservation of moisture. Understanding the freeze-thaw process with the knowledge of antecedent soil moisture content will help determine the potential success of snow management practices.

The type of tillage used for summerfallow usually plays a relatively minor role in water conservation in most semi-arid regions. However, the type of tillage is critical in terms of soil conservation. When considering the non-growing season, the best tillage practice for water conservation is zero tillage, except where expected evapotranspiration losses through weeds would exceed losses that would otherwise occur because of disturbance of plant residue barriers. The best deterrent for reducing the rate of vapor loss is to provide a barrier in the path of transfer from the evaporating surface to the atmosphere. Maintaining an adequate crop residue cover (1500-2000 kg/ha) is critical for success with minimum tillage systems. Tillage can often affect short-term moisture conservation and this is particularly critical for seedbed preparation in recropping systems.

The crop-fallow system reduces yield variability by storing some soil water for the subsequent crop year but summerfallow is the cause of many of our soil erosion and salinity problems. The efficiency of summerfallow must be improved in those regions where it is appropriate, but in many regions summerfallow is unnecessary and extended cropping rotations would improve the overall water use efficiency of limited supplies. The use of annual legumes as a cash crop or a green manure in a cereal rotation can make more effective use of water and improve soil quality compared to traditional summerfallow. Management systems that involve the conservation of crop residues could help reduce evaporation losses and increase soil water storage. Crop residues also absorb the impact of raindrops, help maintain higher infiltration rates, and slow runoff. Effective management of crop residues with limited tillage can improve soil conservation and reduce the risks associated with recropping systems.

Minimum tillage systems have been effective for controlling soil erosion, runoff, and water pollution. Furthermore, there is a complementary relationship between minimum tillage and soil, water, and energy conservation. However, the limited adoption of minimum tillage or no-till has illustrated that there are still problems associated with these systems that must be overcome. Many of these problems with minimum tillage are related to management and timely weed control, but these problems will be overcome as producers get more experience with these systems. Probably the most critical problem limiting widespread adoption of minimum or zero tillage is the high cost of the most suitable herbicides in relation to the cost of conventional cultivation. There is little, if any, short-term economic incentive for producers to adopt the most effective minimum tillage practices. The adoption of the most effective minimum tillage and cropping practices would virtually eliminate our serious soil degradation problems and ensure that soil productivity is maintained for future generations. Producers should not be expected to bear all of the costs associated with the adoption of recommended management practices when society receives most of the benefits.

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SNOW TRAPPING AND MOISTURE INFILTRATION ENHANCEMENT

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ABSTRACT

Generally, snow constitutes over 25 percent of the amount of precipitation on the Canadian prairies. Water equivalent of the snow varies between 70 - 140 millimeters per year. Various techniques to trap snow have been studied by Agriculture Canada and the University of Saskatchewan since 1973 Snow trapping efficiencies as high as 99 percent have been observed. The depth of snow trapped was closely related to the height of vegetation when snowfall, fetch, vegetative cover and other conditions favour the transport and deposition of wind blown snow.

The amount of water from trapped snow that can be stored in the soil profile was found to be highly variable. Snowmelt infiltration studies indicate that a direct association between snow cover depth and snowmelt infiltration should not be expected because of differences in the physical properties of the snow cover, seasonal ablation process, soil moisture and soil temperature regimes at the time of melt.

Preliminary studies also suggest that to maximumize water recharge from snow management practices, it is necessary to combine them with tillage practices such as subsoiling that increases the macropore content of the soil at the time of melt. Data are presented to demonstrate that "ripping" to a depth of 600 mm increases the water intake on the average of six times the amount compared to undisturbed stubble depending on the available snow water equivalent. The increases are in the same order of magnitude found in heavy clay soils that naturally fracture when dry.

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SNOW TRAPPING AND MOISTURE INFILTRATION ENHANCEMENT

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INTRODUCTION

The prairie farmer plays a vital role in the management of soil and water. Some of the more pressing problems facing the producer are soil erosion by wind and water, soil degradation due to salinity, and the loss of organic matter. Research has shown that extending the cropping system can increase organic matter, control salintiy and reduce soil erosion. However, continuous cropping increases the risks of poor yields in dry years and so it may not be a practical alternative for farmers facing high annual production costs. This is particularly true in the brown and dark brown soil zones of the prairies. Retaining the snow where it falls improves the potential of water conservation and thereby soil conservation.

"Manipulation of snow cover offers the greatest potential for increasing available water for dryland crops on the Canadian praries" (Rennie 1979). Snow management to increase soil water conservation requires that snow be trapped, distributed and held on the field until the crop has grown. This also means that on melting, the water should have a good opportunity to enter the soil rather than be lost by runoff.

This paper will review the advances made in the trapping of snow and examine the potential for meltwater enhancement.

SNOW MANAGEMENT PRACTICES

Snow management implies the use of a physical barrier to trap snow uniformly on a field where it is held until a crop is grown. Barriers for snow management can be grouped into competitive and noncompetetive types, depending upon whether the barrier competes with the crop for the stored soil water supply.

Noncompetitive Barriers

Stubble management is the most viable snow management practice for the prairies because of the type of crops grown and nature of cultural operations. The most popular methods include tall stubble, alternate height stubble, trap strips and leave strips.

Tall stubble. The term "tall" stubble is used in a "relative" sense to infer that the crop is cut at the highest possible height during the harvesting operation thus leaving a field of "high" stubble. Normally this practice is used when the crop is straight-combined. The actual height of a "tall" stubble is a function of the crop variety, plant density and crop height but usually will fall in the range from 30 to 60 cm.

Studies on the use of tall stubble for trapping snow were conducted by the Division of Hydrology at Saskatoon and Port Reeve (Nicholaichuk et al. 1985). Based on average stubble height differential of 6 cm between conventional stubble height and tall stubble height suitable for straight combining, the net increase in snow water equivalent available for soil recharge was 1.6 cm. Consequently the amount of moisture that can be gained by utilizing "tall" stubble is limited by the height of stubble.

Alternate-height stubble. Swathing at alternate heights is a form of snow management that has been investigated for a period of 13 years at the Swift Current Research Station (Nicholaichuk et al. 1985). Treatments consisted of alternately swathing the wheat crop at two different heights using a self-propelled swather. The heights are dependent on the crop stand condition. The control consisted of wheat that was swathed at a uniform height.

The average depth of snow trapped by non-uniform stubble was 4 cm. or 22% more than on the uniform stubble. Additional soil water increase from trapped snow was 1.4 cm or 23% greater indicating an approximate linear relationship between snow depth and moisture equivalent.

Trap-strips. A concept developed in 1979 consists of leaving a strip of tall standing stubble that acts as a barrier to trap snow on stubbled fields. Development of the concept was continued during 1979 and 1980 with two Agriculture Canada AERD contracts with the Department of Agricultural Engineering of the University of Saskatchewan (Steppuhn, 1980). At Swift Current two types of strips spaced at 6.4 m are being evaluated. The first type consists of leaving a strip of tall standing stubble that is created by using a deflector-type attachment mounted on a conventional swather. The second type of leave-strip is created by using a clipper type of attachment mounted on a conventional swather which leaves a narrow strip of standing stubble with the heads clipped off (Dyck et al. 1982).

Only 3 years of study have been devoted to this trap system of snow management. The clipper system tended to trap more snow than the deflector attachment. The clipper system left more erect standing stubble that tended to provide additional turbulence for compacting snow within the tall strips of tall standing stubble. On the average, the clipper system trapped 15 percent more snow than the deflector system. In addition, the clipper system trapped 39 percent more snow compared to the uniform stubble check.

Trap strips, either the deflector or clipper type, were on average 20 and 36 percent more effective in trapping snow over the same three year period compared to the alternate height stubble method. In comparing the two systems, the trap strip offers a greater potential capacity because of the physical configuration.

In terms of soil water storage, at Swift Current, the three year study showed the trap system by either the deflector or clipper method increased the stored water by as much as 2.2 and 3.6 cm respectively. This increase in water storage represents an intake efficiency of 62 percent for the deflector and 74 percent for the clipper compared to 38 percent for the check.
In other words, the intake efficiency for the clipper is near double the control. In comparison to the alternate stubble heights the intake efficiency was found to be considerably higher than either control or the alternate height system. This suggests that a barrier created by the clipper system may act as a heat sink during the thaw period resulting in increased moisture trap.

In contrast, similar studies conducted by Chanasyk (1985) in central Alberta showed snow trapping using trap strips did not enhance moisture gain significantly at any of the sites in any of the three years of study from 1982 to 1985. No trend of higher or lower moisture gain was evident for the stripped treatment, in spite of a wide range of fall moisture contents.

Leave strips. In this practice, 30 to 40 cm wide strips of crop, spaced 1, 2 or 3 swather-combine widths apart are left unharvested to act as barriers to trap snow (Nicholaichuk et al 1985).The width of a swather usually is in the range from 4.6 to 7.6 m. With a 30 cm. wide strip placed on a 15 m. spacing, approximately 2% of the area of a field is left unharvested.

A particular advantage in cutting a field to leave stubble at different heights is that the vegetative surface formed is aerodynamically rougher than that of a uniform stubble; consequently, its snow trapping efficiency is higher. The practice would be favoured where crop conditions, principally density and height, are insufficient to provide a "tall" dense stubble and on highly-exposed topographic facets, e.g. the tops of ridges and knolls.

Based on four years of data from Saskatoon and Port Reeve approximately twice as much water was trapped by this technique compared to the control. The maximum differential of additional water trapped observed in the four years of study was 8.9 cm which is somewhat higher than the clipper system.

Competitive Barriers

The Tall Wheat Grass barriers concept developed in northern Montana (Black & Siddoway 1976) and later studies at Swift Current has been found to be effective for trapping snow (Nicholaichuk et al 1985). Barriers consist of tall wheat grass planted in single or double rows spaced 9 m to 15 m apart. The grass barrier offers a greater potential for trapping more snow than the non-competitive types. This is mainly attributed to the fact that the tall wheatgrass provides a barrier that is a meter in height or more. Five years of data suggest that the barrier system traps approximately twice as much snow compared to the uniform stubble.

Not only did the barrier system trap offer an opportunity to trap more snow, the net increase in water stored was 73% greater than the control. Results to date are similar to those reported by Black and Siddoway (1976).

SNOWMELT INFILTRATION

Infiltration to frozen soils involves the complex phenomenon of coupled heat and mass transfer through porous media. The process is affected by many factors including: the hydrophysical and thermal properties of soil; the soil moisture temperature regimes; the rate of release of water from the snowcover and the energy content of the infiltrating water. However it is recognized the most important hydropyhsical property of a frozen soil that governs its ability to absorb and transmit water is its moisture content.

Granger et. al. (1984) undertook an extensive field study of snowmelt infiltration to frozen, medium to fine-textured soils in central Saskatchewan. The study resulted in the development of a simple physically-based model describing snowmelt infiltration into frozen soils (Gray et al. 1985). Three categories with regard to infiltration potential were identified. Namely:

Restricted - infiltration is impeded by an impermeable layer, such as an ice lens at the soil surface or within the soil near the surface .

Limited - infiltration is governed by the snowcover water equivalent and the frozen water content of a shallow layer of soil, 0 - 300 mm.

Unlimited - a soil in this condition contains a high percentage of large air-filled, non capillary pores or macropores or macropores at the time of melt and most or all the snow water will infiltrate. Examples of such soils are dry heavily-cracked clays and coarse, dry sands.

The latter category lends itself to snow management practices.

Infiltration Into Cracked Soils

Gray et al. (1985) showed that cracked soils have the capacity to infiltrate most or all the water equivalent of an average snowcover and depending on the number, density and physical dimensions of the cracks even heavy snowcovers encountered on the prairies. These soils then offer a high potential for increased infiltration from increased snowcover and as such represent an ideal situation for the implementation of snow management practices.

Granger et al. (1986) observed that texture of soils susceptible to cracking affects the amounts of infiltration. Data (Table 1) suggests that the ability of a cracked soil to infiltrate meltwater is directly related to its susceptibilty to cracking : i.e. : heavy clay soils produce wide and deep cracks and thus can take in a greater quantity of water.

Table 1. Average infiltration into cracked soils. (Taken from Granger et al. 1986)

Soil type	Crack depth m	Infiltration depth m	Average Amount mm
Heavy Clay	0.90	0.95	106
Silty Clay	0.81	0.87	93
Silty Clay Loam	0.73	0.76	78
Silty Loam	0.72	0.75	74

Enhancement of Snowmelt Infiltration

Data collected to date suggest that snow trapping techniques are successful in trapping snow. However, 13 years of data by swathing at alternate heights also suggests the benefits that can be attributed to snow management are highly variable due to reasons given earlier in this paper. To this end, exploratory studies have been initiated to determine whether snowmelt infiltration can be enhanced. (Nicholaichuk et al. 1984, Gray et al. 1985).

Utilizing a conventional subsoiler, a Killefer plow and a Paraplow (registered trademark) (Pidgeon 1983), trial experiments were initiated to determine whether such tillage practices would enhance meltwater infiltration from trapped snow (Nicholaichuk et al. 1984, Gray et al.1985).

From the one year study at Swift Current, Saskatchewan (Nicholaichuk et a.l 1984) subsoiling or paraploughing between the strips of tall standing stubble did not appear to reduce the depth of snow trapped. The practice of 'Paraplowing' did have a beneficial effect of enhancing snowmelt infiltration when compared to the control. The benefits attributed to these types of tillage practices are related to the amount of snow entrapped. On uniform stubble, when a smaller amount of potential stored moisture was trapped, tillage had a detrimental effect on the amount of water that was store.

Preliminary data (Table 2) suggests that "naturally-cracked" heavy clays and "ripped" subsoiled soils offer high potential for soil water augmentation by snow management practices (Gray et al.1985). On average, depending on the available snowcover water equivalent, water intake in fractured soils was in the order of 6 times the amount of infiltration to undisturbed stubble.

Table 2. Mean ratio of the amount of snowmelt infiltration in a cracked or subsoiled soil to the amount in the same soil in an uncracked or undisturbed condition for different ranges of snowcover water equivalent. (From Gray et al. 1985)

		Subsoiled		
SWE[a] mm	Cracked[b]	300 mm[c]	600mm[d]	Paraplowed
<30	4.5	1.1	---	1.5
30-50	2.9	0.7	---	0.7
50-70	4.1	---	---	---
70-100	4.7	1.8	6.9	1.5
100-150	7.5	0.8	6.8	1.2
>150	---	---	6.7	---

[a] SWE = snowcover water equivalent

[b] Measurements of soil moisture changes made with the crack located between source and detector.

[c] Ripped to depth of 300 mm on 1-m spacings; loam soil at Swift Current. Measurements of soil moisture changes taken at 300 mm intervals to a depth of 1.2 m.

[d] Ripped to a depth of 600 mm on 1.85-m spacing with a Killefer plow; clay loam and clay soils at Kerrobert. Measurements of soil moisture changes made with the rip located between the source and the detector.

Studies to date suggest water augmentation practices by deep ripping or paraploughing appear to be beneficial provided sufficient snow is trapped by standing stubble.

FUTURE OF SNOW MANAGEMENT AND MELTWATER ENHANCEMENT

Snow management studies to date have identified a number of deficiencies that need to be addressed such as equipment requirements, area extent of applicability of the practice, probability of moisture storage from snowtrapping without meltwater enhancement, benefits and economics of meltwater enhancement, impact of snow management practices on surface runoff and groundwater recharge etc. Some of these concerns are being addressed in current studies that are presently underway.

Although considerable effort has been made to develop equipment to create trap strips in standing stubble (Dyck et al. 1982), suitable equipment has not been perfected that could be used to create a trap strip in drought years when grain height is limited. Use of simple, low cost deflectors have not become popular because of some of the inherent operational difficulties when grain height is limited. Excellent progress has been made by entrepreneurs such as Merv Lloyd from Darcy, Saskatchewan in the development of a clipper attachement that can be universally mounted on any make of swather. As new equipment ideas are developed, there is a need for equipment evaluation so that appropiate recommendations can be made by extension personnel. Availability of appropiate equipment is vital to the adoption of snow management practices by producers.

The question of areas of applicability of snow management practices especially in the Chinnok belt of the southern prairies needs to be addressed. Studies at Swift Current (Nicholaichuk et al. 1985 a) over a thirteen year period suggest that the amount of water stored as a result of snow management can be highly variable. However, other studies at Swift Current have shown that benifits in added crop yields can be attributed to microclimate effects of trap strips even though moisture gains were minimal (Campbell et al. 1986). Effects of barriers on the micro-climate have been examined by Black and Siddoway (1976) at Culbertson Montana and were shown to have an effect on the reduction on evapotranspiration. Preliminary studies at Swift studies by Nicholaichuk (1981) confirmed the studies at Culbertson. Observations by Markle (1986), a producer at Claresholm Alberta suggests that tall uniform stubble not only traps snow for added soil moisture but does lower the wind velocity at the ground surface resulting in reduced evaporation. Drawing on these results, the use of trap strips in the Chinnok zones of the prairies should have a positive effect even though snow cover may be intermittent for the area.

An unpublished report by Heywood (1986) suggests that snow management practices would have a larger potential impact during wet years than dry years for southern Alberta. In addition, snow management practices may result in sufficient moisture to make annual cropping economically viable.

In the black and grey soil zones of the prairies, snow management practices may not be beneficial. With a shorter growing season in these regions, tall stubble for snow trapping may result in a longer period of time for soil temperatures to rise. In addition, added soil moisture may simply delay normal seeding operations. Consequently, further studies are required to determine optimum stubble management practices that would result in added soil moisture storage without hampering cultural operations.

The rate of adoption of snow management practices without meltwater enhancement has been reduced when producers realized results of the practice were highly variable. As shown by Gray et al. (1985), the amount of infiltration can be minimal in situations where infiltration is impeded by an impermeable layer such as an ice lens or in situations where the infiltration capacity is limited. Granger et al (1984) found heavy clay soils that naturally fracture are receptive to meltwater infiltration . Such soils lend themselves to snow management practices that can prove to be benificial.

In order to assess the areal extent of snow management practices on the prairie an analysis of textures of soils in the brown and dark brown soil zones of the prairies indicates approximately 20,739,000 hectares out of 43,082,000 or 48% of the cultivated area is either classified as clay or clay loam (Table 3). On these type of soils that naturally crack, studies to date suggest that snow management without snowmelt enhancement can be very beneficial. Additional studies are required to fully assess the benifits of snowmelt augmentation practices on the loam and sandy loam soils.

Table 3. Cultivated area (thousands of hectares) of soil classes in the Brown and Dark Brown Soil Zones on the Prairies. (Unpublished data. Personal Communication, J.A.Shields, Western Correlator,Land Resource Research Institute, Ottawa, Ont.)

ZONE	SAND	SANDY-LOAM	LOAM	LOAMY-CLAY	CLAY
Brown	241	306	8646	10390	1559
Dark Brown	---	2320	10830	5251	3539
Total	241	2626	19476	15641	5099

The impact of snow managment practices on surface runoff and groundwater recharge have not been fully examined. Nicholaichuk et al. (1983) showed that runoff was inversely related to infiltration. This study showed that trapping snow by swathing at alternate heights did not adversley affect the amount of runoff.Depending on topography, soils type and climatic conditions snow trapping may result in added runoff that may result in added erosion.

SUMMARY

Extending the cropping system has been said to be the answer to overcome the problem of land degradation faced by many producers in Western Canada. However, the yield variability has to be reduced if this system is to become acceptable. The answer appears to be in the more efficient moisture management systems that includes snow management.

Recent research suggests that snow management practices can substantially augment soil water reserves. The potential impact of these practices is variable due to a number of factors such as soil type and climatic conditions.

Preliminary snowmelt infiltration studies indicate that naturally cracked soils are ideal for snow managment for obvious reasons.Although preliminary studies suggest that mechanically fracturing of soils (ie. subsoiling) can be beneficial, the limitations and economics of these tillage practices have not been fully assessed.

Although all the research information is not available at this time,there are a few statments that can be made with respect to the impact of snow management and meltwater enhancement on crop production. These are:

1. On the average, half of the annual snowfall can be trapped by the use of stubble or permanent grass barriers. Grass barriers offer the greatest potential to trap the most snow.

2. Depending on climate and soil conditions, sufficient water can be stored to eliminate the need for summerfallowing.

3. Stubble or grass barriers alters the microclimate next to the soil surface by reducing windspeeds and evaporation which has a positive impact on crop yields.

4. Snow managment on soils that naturally fracture should be a recommended practice. Approximately 48% of the cultivated soils are clasified as clay or clay-loam.

5. Tillage practices to enhance meltwater infiltration show promise but require further study.

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WEED MANAGEMENT FOR CHANGING TILLAGE SYSTEMS

E.H. Stobbe, Professor

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Traditionally farmers have depended on tillage to control weeds prior to seeding. I am calling this tillage method "conventional tillage".

The development of selective herbicides has allowed the farmer to reduce his tillage operations, since some of the weeds, particularly winter annuals and broadleaf perennial weeds have been controlled with 2,4-D and/or dicamba. The use of these herbicides has reduced the tillage operations to control weeds and I am calling this tillage method "minimum tillage".

With the advent of non-selective herbicides, such as paraquat and glyphosate, it is now possible to kill all weeds chemically prior to seeding, which eliminates the necessity for tillage for weed control. The crop production system where tillage is not used to control weeds, or prepare a seedbed, I am calling "zero tillage". Based on this definition the amount of soil distrubance may not be the critical factor, rather that the farmer does not depend on tillage for weed control.

A large are of the Canadian prairie appears to be too dry for continuous cropping. In these areas a tilled summerfallow has been the conventional practice.

Recently a number of herbicides have been introduced to reduce the tillage operations in the fallow year. Products such as paraquat and glyphosate, together with broadleaf herbicides have been used to control all vegetation in the fallow year, without the use of tillage, and this practice has been called chemical fallow.

In addition, minimum tillage fallow systems have been developed using trifluralin and chlorsulfuron. Although these systems do not eliminate tillage, besides controlling the weeds in the fallow year, they appear to reduce the weed problem in the subsequent crop.

Although most weeds can be adequately controlled in minimum and zero tillage systems, there have been some weeds that have caused particular problems, such as foxtail barley and wild rose.

Zero and minimum tillage have created a dependance by the farmer on herbicides. When grain prices are high these costly inputs can be covered based on a consideration of long term benefits of reduced soil erosion. On the short term these farmers may, however, experience severe financial hardships.

WEED MANAGEMENT FOR CHANGING TILLAGE SYSTEMS

Elmer H. Stobbe, Professor

Traditionally farmers have depended on tillage to control all the weeds prior to seeding their crop. I am calling this tillage method conventional tillage. When summerfallow is practiced, or when perennial weeds are a problem, conventional tillage has resulted in exposing the soil to the erosive forces of wind and water. In addition, weed control has not always been satisfactory, particularly when perennial weeds are a serious problem.

The introduction of agricultural chemicals to control weeds has allowed farmers to change their tillage practices. Selective and non-selective herbicides have been used to control both annual and perennial weeds. Herbicides, such as 2,4-D and dicamba (Banvel), have been used by farmers to control broadleaf annual and perennial weeds in the summerfallow year. In areas where continuous cropping is practiced, 2,4-D and Banvel have been used to control fall germinating annual weeds, and perennial weeds after the crop has been harvested. The use of these herbicides has reduced the number of tillage operations required to maintain summerfallow in a weed free condition, and the number of tillage operations required to control weeds under continuous cropping. This tillage system in which herbicide are used to reduce the tillage operations to control weeds, I am calling minimum tillage.

Recently, with the introduction of non-selective and short term residual herbicides, summerfallow has taken on a new name, chemical fallow. Strictly speaking, the term chemical fallow should be preserved for a summerfallow without the use of any tillage. However, the term chemical fallow is also being used where one or two tillage applications are used to reduce the cost of herbicides in the summerfallow operation.

On the extreme right end of the tillage spectrum we have zero tillage (no till). Zero tillage has been defined as a cropping practice where all unwanted vegetation is controlled using herbicides, and the crop is seeded in a manner so that the soil disturbance is less than 25%. I would like to change that definition slightly, since I feel that the level of soil disturbance should not be included in the definition. My definition of zero tillage is as follows: Zero tillage is a cropping practice where all unwanted vegetation is controlled using herbicides, and the seeding is done with a minimal soil disturbance. Zero tillage does not eliminate soil disturbance, but it should not be considered tillage since the seeding operation is not used for seedbed preparation or vegetation management.

Weed Management Under Reduced Tillage Systems

Continuous Cropping

Annual weeds. Seeds of most annual weeds (wild oats, green foxtail, wild mustard, smartweed, wild buckwheat) must be buried in the soil before they will germinate and grow. Under zero tillage, seeds are left on the soil surface, and one might assume that the annual weed problem has been solved. In practice the situation is not so clear cut. The agricultural soils of the Canadian prairie are heavily infested with weed seeds which can remain dormant in the soil for a number of years. The dormancy of these seeds is broken under the cool, moist conditions in the soil and each spring a new flush of weeds can emerge, even though no additional seeds are buried with tillage operations. Even under zero tillage some weed seeds find their way into the soil. Some seeds are buried by the seeding operation, while others fall into cracks in the soil.

Annual broadleaf weeds which emerge before the crop are easily controlled using herbicides, such as 2,4-D, MCPA, Banvel, bromoxynil (Pardner or Torch), or chlorsulfuron (Glean). Although Glean provides a wide range of broadleaf weed control, because of its persistence and soil activity it is limited to soils with a low pH and to areas where cereals are not rotated with broadleaf crops such as canola, sunflowers or sugar beets.

In most continuous cropping areas, annual grassy weeds, including volunteer cereals, are the most serious weed problem at the time of seeding. Glyphosate (Roundup) and paraquat (Sweep) will kill all seedling grassy weeds, as well as a number of broadleaf weeds.

Our research has shown that annual weeds can easily be controlled using herbicides, however, that does not mean that they are currently cost effective for the farmer to use.

In-crop weed control can be a serious problem in some crops, particularly canola. Recently Lontrel was recommended for Canada thistle control in canola, as well as Poast for grassy weeds, including volunteer cereals. There are, however, a number of broadleaf weeds that we currently cannot control in canola, including wild mustard, stinkweed, and wild buckwheat. A new chemical, developed by DuPont, is currently being evaluated for the control of wild mustard and stinkweed in canola. When this new chemical becomes available to the farmer, it will be possible to extend the area in which canola can be grown under reduced or zero tillage systems. Currently, farmers will have to depend on soil incorporated herbicides, such as trifluralin, for weed control in canola.

Perennial weeds. Tillage has been the traditional method to control perennial weeds. In the area where continuous cropping is possible, many fields are still being summerfallowed, primarily to reduce the problem of perennial weeds.

In southern Manitoba, with a relatively long growing season, and moist conditions most years in the fall, perennial weeds, such as

Canada thistle and quackgrass, will regrow after the crop has been harvested and can be treated with a herbicide before freeze-up.

Roundup can effectively be used for quackgrass control in the fall, and best control will be obtained when the affected areas are tilled 7 to 10 days after herbicide application. Some control of quackgrass can also be obtained with Poast applied as an in-crop treatment in most broadleaf crops.

Canada thistle can be treated in the fall with Banvel, alone or in combination with 2,4-D, after harvest. Although this treatment will not kill the Canada thistle, it will reduce its vigor, and make it more susceptible to in-crop treatments of 2,4-D, Banvel or Lontrel.

In the drier areas, and the northern areas of the prairies, perennial weeds seldom have sufficient regrowth after harvest to be treated with herbicides in the fall. Quackgrass can pose a particularly severe problem in these areas. Delayed seeding after Roundup treatment in the spring is not always practical, since the quackgrass utilizes soil water for establishment in the spring and the delay in seeding may severely reduce the yield potential of the crop. On fields where quackgrass is found in patches, the farmer may consider applying Roundup to the patches after the quackgrass is 8 to 10 inches tall. This treatment will kill the crop, but very little crop will be obtained in the quackgrass infested area. When quackgrass uniformly infests the whole field, the farmer has a real problem. In some areas chemical fallow may be the correct answer. In this case the stubble should be left undisturbed and Roundup should be applied when the quackgrass is 12 to 16 inches tall. At the first appearance of regrowth, the quackgrass should be tilled. A second tillage may be required before freeze up.

Other perennial weeds which can cause severe problem under zero tillage are wild rose, foxtail barley and dandelion. Easily controlled with tillage, these weeds are controlled with difficulty under zero tillage. Foxtail barley can be controlled with Roundup and Glean and Lontrel gives reasonable control of dandelions. Wild rose is difficult to kill, and at the present time we have no registered herbicide that will give effective control of wild rose.

Cereal - Summerfallow Rotations

Although many arguments can be made against the use of summerfallow, in the drier areas of the Canadian prairies, crops may not successfully be grown on an annual basis. Most of the detrimental features of summerfallow are associated with tillage required to control weeds. As already mentioned, the development of herbicides has allowed farmers to reduce the number of tillage operations to maintain a weed free fallow.

Chemical fallow systems.

Winter annuals. Winter annuals must be controlled in fall. Most winter annuals can easily and inexpensively be controlled using 2,4-D. The development of Glean has added a new dimension to the control of winter annuals. Not only are the weeds that emerge in the fall controlled, but Glean residues in the soil will also control the winter annuals that germinate early in the spring.

Spring germinating annual weeds. When Glean is applied in the fall, residues will persist throughout the fallow year to control most broadleaf weeds. Grassy weeds and the volunteer crop must be controlled when when the seedlings are in the 3 - 4 leaf stage using either Roundup or Sweep. In some cases no weeds will germinate after the first flush is killed. Commonly, however, more weeds will germinate, and a second, and at times a third, application of Roundup or Sweep must be applied to maintain the chemical fallow. Because of the high cost of herbicides, most farmers are controlling the second and third flushes of weeds with tillage.

Canada thistle. Canada thistle infestations can effectively be reduced in the fallow year. Recent studies by Jim Hunter at the Regina Research Station have shown that Canada thistle is a long day plant. The days of June and July are long enough for the plant to produce flowers and set seed. Under Canadian prairie conditions the photoperiod after the first of August is insufficient to induce flowering. Under these conditions the plants remain in the vegetative phase, producing low growing rosettes with large, tender, healthy leaves. These plants produce a large amount of food materials, which move into the root system for storage. Canada thistle plants treated with a translocated herbicide at the rosette stage in mid-August have been effectively controlled. Based on this method, the top growth of Canada thistle plants that emerge in May to July must be controlled with with intensive tillage or use of burn down herbides, such as 2,4-D. In August the plants are allowed to grow until they are 4 to 6 inches tall, then sprayed with an effective translocated herbide such as Banvel, Glean or Roundup.

Minimum tillage summerfallow. During the past few years Elanco has been developing a minimum tillage fallow system using trifluralin (Heritage). This system begins with a fall treatment similar to the chemical fallow system described above. Again Glean would be the herbicide of choice, since the residues give broadleaf weed control in the fallow year. Heritage is applied in the end of May or early June and incorporated with one tillage operation. Some weeds will escape and a second incorporation must then be done in early July. In most cases, this treatment will maintain a weed free fallow.

Heritage residues can persist in the soil into the following crop year, and frequently will reduce the problem of wild oats and green foxtail in the crop. There are, however, some dangers when using Heritage during the fallow year. If the summer has been drier than normal, or if the farmer has applied too high a rate of the chemical, some injury can be observed in the following crop. The success of the Heritage fallow system will, therefore, depend on good management in the use of the chemical.

Zero Tillage Winter Wheat Production

Traditionally winter wheat has been grown in southern Alberta and south-western Saskatchewan. The development of zero tillage winter wheat production has allowed farmers in most areas of the prairies to grow winter wheat. The stubble from the previous crop traps the snow, covering the winter wheat seedlings with a protective blanket. The trapped snow also provides additional moisture in the spring. In the spring there is no soil disturbance to prepare a seedbed or to seed the crop, allowing for maximum water use efficiency by the crop. Winter wheat initiates growth early in the spring, and by the time spring germinating annual weeds emerge the crop is well established. Spring germinating weeds seldom cause economic grain losses. Annual weeds can, however, cause severe problems in areas where the stand is poor, most frequently associated with winter kill.

Fall germinating winter annuals can cause problems in the crop and should be controlled in the fall. Currently the only herbicides that are recommended for fall application to control winter annuals are Glean and bromoxynil + MCPA (Buctril M). The chemical residues in the soil from fall applied Glean will also control spring germinating broadleaf weeds. Although 2,4-D and MCPA are not registered for fall application in winter wheat, they have been widely used and, at the rates used, have not caused any harmfull effects on winter survival.

Perennial weeds can cause severe problems in winter wheat. Fields that have problems with quackgrass, and foxtail barley should not be seeded with winter wheat. Downy brome, a winter annual in some areas, can also cause severe problems in winter wheat.

Although most of the winter wheat is seeded as a recrop, some farmers in the drier regions have successfully seeded it into an area that has been in chemical fallow (no tillage used during the fallow year). The stubble density in the chemical fallow is not as high as when the crop was first harvested, and less snow will be trapped by the stubble. Weeds, both annual and perennial, can effectively be controlled in the chemical fallow year, and provide an excellent rotation with wheat on fields infested with perennial weeds.

New Herbicides For Conservation Tillage Systems

Grass killers. There are several new grass killers with a spectrum similar to Poast. It would appear that some of these chemical give better control of quackgrass than Poast.

Broadleaf killers. DuPont has a number of chemical that have a similar weed spectrum as Glean, but do not persist as long in the soil. These chemicals could be used in areas where soil residue persistence causes a serious problem in the succeeding crop.

Broad spectrum killers. Over the past 6 -8 years Stauffer has been developing a Roundup look alike. This chemical has not been registered, but research with the product is still continuing. The other broad spectrum herbicide that has been under test for a number of years is Basta, developed by Hoechst. Basta gives a faster killing action than Roundup, not not as rapid as Sweep. Basta translocates to some extent in the plant, but not as much as Roundup, and the control of most perennial weeds is marginal.

Herbicide Costs For Conservation Farming

Chemical companies are entrepeneurs. The price they charge for the herbicides is what the traffic will bear. Since the herbicides are sold on a global basis, each product has a diverse market potential. The herbicide pricing is established for the high value crops or uses. Unfortunately, the crops we grow on the Canadian prairie are low value crops, and the price we must pay for the herbicides appears to be excessive. Herbicides are unique and patentable, and direct competition for a particular herbicide may not exist. The patent life of herbicides is 17 years. Pesticides, including herbicides, are considered environmental pollutants. With the sophisticated equipment that we now have available, we can now detect pesticide residues that were undetectable when a particular herbicide was registered. In addition, the department of environment is demanding new, and often very expensive additional tests, before it will allow the product to remain on the market. Companies are being required to pay for the extra costs and are passing the costs on to the consumer, the farmer. The costs may not be passed on by charging more for the product, but by obtaining extended patent protection.

Within the next 5 years the patent on a number of the more popular herbicides will be expiring. It is still unclear whether these products have any patent extensions, and when they will become generic products.

Abstract

PERFORMANCE OF CROPS AND WATER USE EFFICIENCY

R. C. McKenzie, R. P. Zentner and C. A. Campbell

This paper reviews some of the factors that influence water use efficiency of crops. Crops are able to use water more efficiently and produce more dry matter per unit of water as the carbon dioxide level of the atmosphere rises. Water stress on the crop can be caused by chemical characteristics of the soil. Plants have difficulty in obtaining water from soils which are saline or acidic.

Crops differ in their ability to use water. In the warmer areas of the Prairies corn, millets, pigweeds and kochia all offer possibilities of making better use of available water than the small grains, oilseeds and forages that are usually grown. Plants which are tolerant of cool growing conditions can make better use of available moisture when grown as winter crops. Characteristics and techniques have been established by wheat breeders to select wheat cultivars for drought resistance. As the amount of water used by crops increases, the efficiency of crops also increases if the system is designed to make use of this extra water.

Cultural practices also have an effect on water use efficiencies. It has been shown that ridging of the soil or covering part of the soil's surface should increase the yield and the water use efficiency of crops grown on the remaining area. Wheat-fallow rotations make use of only part of the available moisture below 90 cm. The amount of grain that was produced by an additional unit of water was reported for dryland wheat at Swift Current as 6.7 and 7.8 kg/ha/mm respectively for stubble and fallow. At Brooks and Outlook hard wheat yielded respectively 15 and 10 kg/ha/mm above threshold moisture limits of 50 mm for hard wheat and 75 mm for soft wheat. The economic value of an additional unit of water was reported for fallow and stubble at Swift Current.

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ABSTRACT

This paper reviews some of the factors that influence water use efficiency of crops. Crops are able to use water more efficiently and produce more dry matter per unit of water as the carbon dioxide level of the atmosphere rises. Water stress on the crop can be caused by chemical and physical characteristics of the soil. Plants have difficulty in obtaining water from soils which are saline or acidic.

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PERFORMANCE OF CROPS AND WATER USE EFFICIENCY

Introduction

This paper discusses the major factors that influence the performance of crops in an environment where water is usually deficient. Crops are influenced by their metabolism and photosynthetic characteristics, rooting patterns, leaf shapes, and structure of the plants, their inherent tolerance to moisture stresses and efficiency in the use of water. Soil characteristics and soil management practices, climatic conditions and atmospheric CO_2 levels influence the availability and storage of water. Overriding all of these are the economic limits which commercial farmers face in crop production.

Most agriculture of the world faces an intermittent or continuous water shortage; therefore we are forever trying to get the most production from a limited or irregular supply of water. This has been the predominant factor in western Canadian agriculture for the past century. This review will focus on the Western Plains but will touch on agricultural information from other areas. From necessity, with the scope of the topic, only fragments of the information available will be included.

Meteorological Factors

It has been stated that carbon dioxide (CO_2) levels in the earth's atmosphere will rise due to the burning of fossil fuels and a reduction of forested areas. This increase began more than 50 years ago. Keeling et al, 1976 reported that the present carbon dioxide level may double by the year 2025. Predictions of the effects of this doubling on world temperature vary from an increase of 3° to 4° C (Ramanathan, 1981). Others suggest a rise in temperature of 0.26° C (Idso, 1982). If this second estimate proves correct the effect of temperature changes on crop growth will be minor.

The popular press and television have frequently pointed to the anticipated rise in temperature due to an increase in atmospheric carbon dioxide concentration. Less well known is what the effects will be from this change in carbon dioxide on the growth of plants and their water use. Kimball, 1983, summarizes the results of 70 reports on carbon dioxide studies in greenhouses and growth chambers. He reports an average of 33% increase in growth due to a doubling in carbon dioxide content. This increase is not well documented for the C4 species which include the tropical grasses such as corn, sorghum and millets, as well as kochia, pigweeds and Russian thistle.

King et al, (1986) report that maize, at Guelph, used water 40% more efficiently when the CO_2 level was doubled (Table 1). These results and that of other workers cited by Kimball (1983) suggest that water use efficiency of crops will increase if world atmospheric CO_2 levels increase.

Table 1. Water use efficiency of maize when grown at low water levels and three carbon dioxide levels. (King et al, 1986)

CO_2 Level µ 1/1	Water Use Efficiency kg/ha/mm
350	9.7
600	13.1
850	15.5

Plants' Photosynthetic Methods

Plants use one of three different photosynthetic methods and these methods have basic differences in water use efficiency. The most commonly known method is the C3 pathway. This occurs in temperate plants including most cereals eg. wheat, barley, rice and many grasses. Most broadleaf crops are C3 species such as sunflower, alfalfa, beans and lettuce. The C3 crops function best at temperatures from 15° to 25° C and have water use efficiencies of 10 to 20 kg/ha of dry matter for each mm of water (Salisbury and Ross, 1978). In Western Canada, the C3 plants make up most of our crops because of their ability to function well under moderate temperatures.

The C4 photosynthetic species include the tropical grasses such as corn, sorghum, millets, Bermudagrass, Sudangrass, and sugarcane. Other C4 species include the amaranths (pigweed family), kochia, Russian thistle and portulaca. These plants function well at higher temperatures than the C3 species and grow best between 30° and 40° C. This explains why some weeds, which are C4 species, grow very slowly until the weather warms up and then grow rapidly. The C4 species use water efficiently producing 30 to 40 kg/ha of dry matter for each mm of water used.

Desert plants that are succulent have the Crassulic acid metabolism (CAM) method of photosynthesis. They include pineapple, aloes and agave. These plants can produce 180 to 200 kg/ha dry matter for each mm of water. They grow slowly and do well at temperatures about 35° C. These CAM plants do not presently have any economic significance in Western Canadian agriculture.

In a northern arid climate like Western Canada most of our crop species have been C3 crops because of their tolerance of cool growing conditions. They may make their most efficient use of available water when grown as winter crops. More of the C4 crops deserve consideration as commercial crops in the warmer areas of Western Canada. Corn has been used as a crop in Southern Alberta and Manitoba. Millets have recently been tested in the annual forage trials at Brooks and have done well in some years. More work needs to be done in Western Canada on breeding and evaluation of the many types of millets. Kochia is being grown in Saskatchewan and is being tested in Alberta. It is a high yielding, high protein forage which will also grow on saline land. Amaranths have been used in many parts of the world as forages, green vegetables and as an edible seed crop. Russian thistle has a high water use efficiency and can produce 73% as much dry matter and 65% as much protein as alfalfa when using half as much water (Hageman et al, 1978).

Plant Breeding Programs

Freyerherm et al (1984) discuss the possibilities of future increases in the yield of wheat from plant breeding programs. They state "where unfavorable environmental conditions and not genetic potential per se limit yields substantial yield increases likely will require more emphasis on stress resistance".

Hurd, 1976, states that plant breeding programs can be designed to select for drought resistance. Working in southwestern Saskatchewan, Hurd and Townley-Smith were successful in selecting Waskana, Wakooma and Macoum durum wheat from a large population of lines which were grown under drought stress conditions. A suitable amount of drought stress and uniform competition was obtained by growing the lines at two locations and planting a row of spring seeded winter wheat between each row of lines being tested. These cultivars had the ability to do well under both the low rainfall conditions of the Brown soil zone and under higher moisture conditions found in the Black soil zone. Hurd (1976) described a number of characteristics of drought tolerant lines which included narrow leaves and low shoot-root ratios. He measured root lengths at 5 to 7 days or determined germination percentage of seedlings grown in manitol (sugar) solutions as measures of drought tolerance. He sought to select a plant which had a deep vigorous root system that was able to extract moisture at depth.

A contrasting view to Hurd's of how to select for drought resistance has been offered by Passioura (1972). He suggests that a plant with a moderate development of roots will, with the least energy, be able to withdraw moisture from the upper meter of soil. A more vigorous root system which Hurd has selected will use extra energy in growth and exhaust the available water supply sooner. Meyer and Alston (1978) show that with a wet subsoil the yield of a wheat plant increased with the amount of subsoil roots, while with a dry subsoil wheat yield decreased as the amount of subsoil roots increased. Passioura's approach may be important if continuous cropping becomes the accepted practice in low rainfall areas. Hurd's type of plants with a vigorous root system should be best able to extract the moisture which accumulates at depth after fallow.

Soils

Agricultural research centres have traditionally been located on highly productive soils. They have then selected varieties and developed practices that are best suited to that area. The Agriculture Canada Research Station at Swift Current has been an exception in that it is centrally located in the low rainfall, Brown soil zone, as is the Brooks Provincial Research Center. In addition, Brooks is located on saline soil and has for years been inadvertently selecting crops for salt tolerance.

The ability of the plant to make use of available water may be limited by the soil's chemical or physical characteristics. In acid soils soluble aluminum levels above 3 ppm limit the development of roots McKenzie and Nyborg (1984). Consequently, the plants grown on these soils are less able to withdraw moisture from lower depths and are thus susceptible to drought. McKenzie and Nyborg (1984) report that in the soils of Northern Alberta and Northeastern British Columbia subsoil acidity as measured by toxic levels of soluble aluminum, is three times more prevalent in the 15-30 cm layer than in the surface 0-15 cm layer.

The methods of improving the plants' ability to extract moisture from soils with acid subsoils include applying lime or growing crop varieties or species which are tolerant to soil acidity. Incorporation of lime into the acid subsoils is difficult and expensive. Movement of lime downwards by leaching is very slow even after six years in high rainfall areas (unpublished data by Penney, 1984, Alberta Agriculture, Edmonton). The best choice is to grow aluminum tolerant species, however, considerable differences exist in aluminum tolerance of wheat (Foy et al, 1967).

Saline soils inhibit the plants' growth due to the osmotic effects of the salts which reduces the plants' ability to absorb water (Thomas, 1980). At Brooks, wheat grown on saline non-irrigated soils showed a negative correlation of growth to soil moisture and to soil salinity. The most saline areas were more moist than the non-saline areas yet unavailability of water reduced the growth of the crop.

To make better use of available moisture on saline sites it is necessary to reduce the amount of salinity present, or to grow salt tolerant crops. Differences in salinity tolerance between species and varieties of crops do exist. While certain cereal and oilseed crops such as six-row barley, sunflowers and safflower have shown moderate tolerance to salinity, some forage crops and kochia are more tolerant (Holm, 1983).

Drought problems can also develop on soils which have compact layers such as solonetzic horizon's or plow pans, which reduce the penetration of plant roots. Deep tillage may reduce the effect of these hard layers.

Ridging to Concentrate Available Water

Water use efficiency can be increased by concentrating the precipitation in a limited area and reducing evaporation on the remaining area. Unger and Stewart, 1983 found that in North Dakota corn grown with ridged surfaces covered with plastic to reduce evaporation or bare ridges to concentrate precipitation increased corn yields and water use efficiency (Table 2) as compared to the control.

Table 2. Effect of evaporation control on yield and water use efficiency of corn. (Unger et al, 1983)

Treatment	Yield kg/ha	Water Used mm	Water Use Efficiency kg/ha/mm
Check	2412	282	9.0
Ridges, bare	2370	250	10.0
Ridges, plastic covered	4120	284	15.6

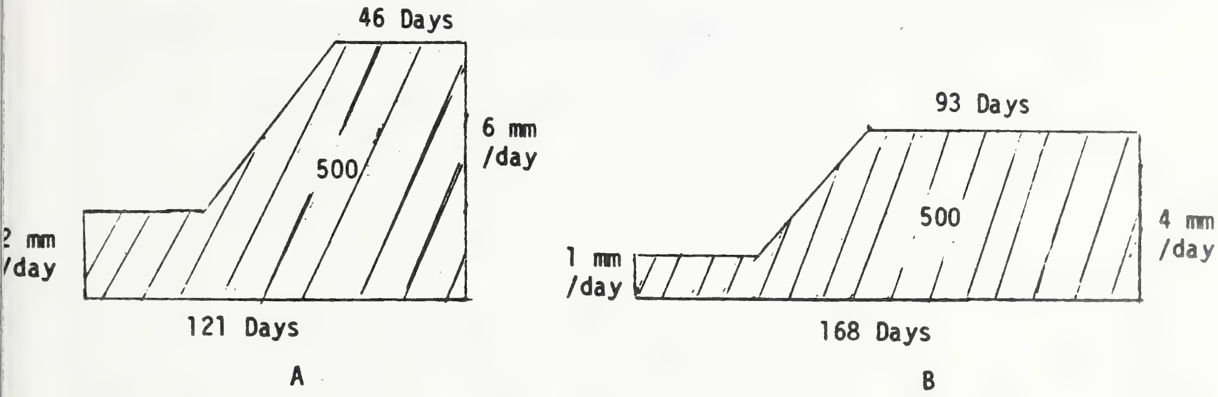
The process of ridging may not be practical for most commercial farming situations but Western Canada now has a large network of uncovered and covered ridges in the form of paved and unpaved roads. Road allowances and highways make up about 2% of the land area in most agricultural regions or about 0.5 million hectares (a million acres) in Western Canada. The road surface only occupies a small portion of the road allowance. The roads are sloped to drain water on the remaining area. New portions of the four lane TransCanada highway near Brooks have 28% of the highway right of way covered by pavement. The moisture supply and yield should increase on the remaining 72% to make it more productive than the original surface.

If road allowances and ditches are to be used for forage or crop production they should be designed and managed accordingly. New ditches are now designed with side slopes which allow use of farm machinery. The custom of using ditches to dispose of bottles causes problems. Broken glass forms a hazard to equipment tires and to livestock which might eat glass fragments included in hay.

Crop Environment

The climatic environment in which the growing crop is found influences its efficiency of water use. Production is usually increased per unit of water if daily water use is reduced. This allows a crop more time to grow and allows for less time for water to evaporate from a bare soil surface. Conditions for low water use occur when crops are grown under low temperatures, when cloud cover is present and when the relative humidity is high. Figure 1 (A) and (B), (Loomis, 1983) illustrate the difference in growing time obtained from two rates of water use with a supply of 500 mm of water. These conditions for low water use time can often be better achieved with winter crops than with spring crops. Winter crops are also better suited to make use of June rainfall to match the crops' peak water use period which is from the shoot to soft dough stage of wheat. Spring crops, if seeded early, can make better use of the low temperature during their growing period than later seeded crops.

Figure 1. Two rates of water use by a crop given a supply of 500 mm.



On dryland at Swift Current a peak yield occurred at a water use of 285 mm for a fallow crop and 255 mm for a stubble crop (Figure 2). This contrasts with Brooks data where McKenzie and deSouza (1985) found that peak yields occurred at 490 mm with Neepawa hard wheat and 540 mm with Fielder soft wheat (Figure 3). The difference between the dryland and the irrigation study results lies in the opportune timing of the water at Brooks as contrasted to the random and limited occurence of rainfall at Swift Current, as well as differences in the fertility status of the soils. The soft wheats and HY320 3M wheat have ability to make use of more water than Neepawa hard wheat.

Figure 2. The relationship between available moisutre and yield of wheat from well-fertilized rotations at Swift Current, (A) Fallow, (B) Stubble (Available moisture = moisture held in the spring in 1.2 m (4 feet) of soil - moisture held at 1.5 m Pa (wilting point) plus growing season precipitation.

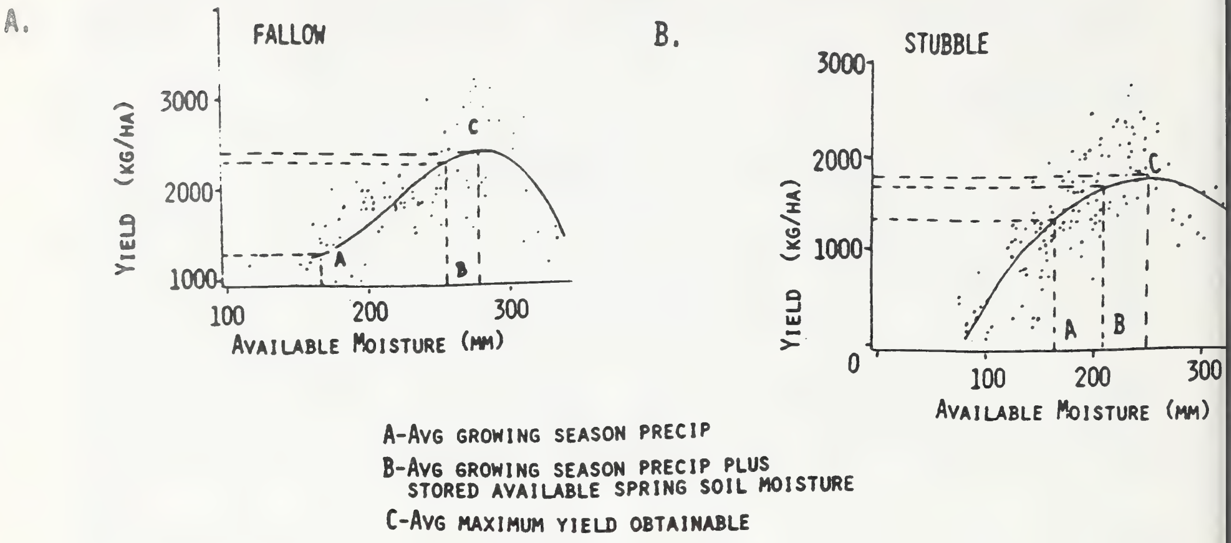
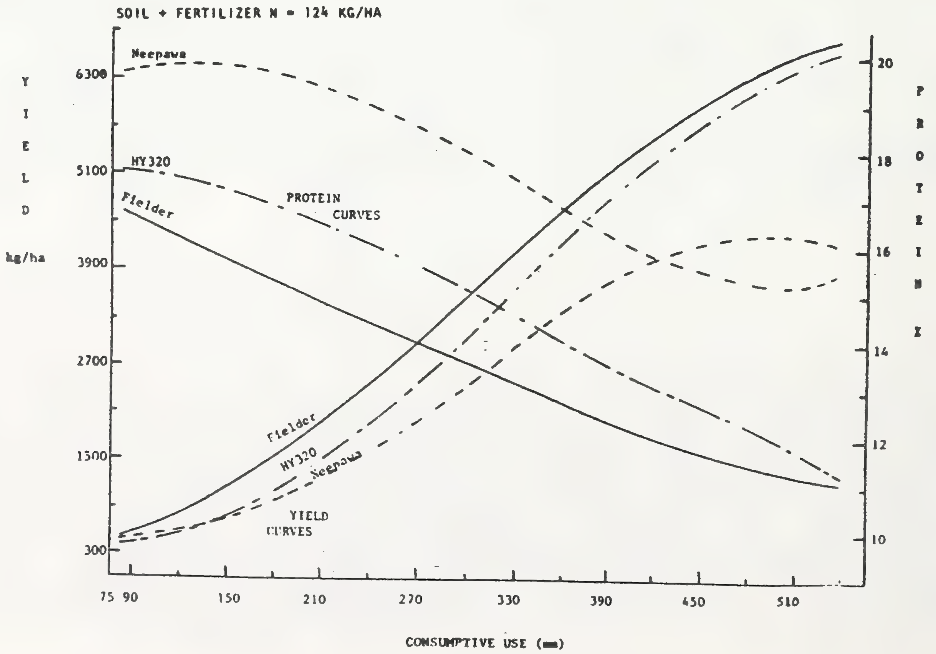


Figure 3. Effect of irrigation water on the yield and % protein of three types of wheat at Brooks.



Moisture Use by Prairie Wheat

When spring wheat was grown in North Dakota the available soil moisture was depleted to 0.9 m (3 feet) but only part of the available moisture was depleted in the next 0.6 m (2 feet) (Bauer and Young, 1969). They recorded an average depletion, over the season, of 96 mm from the first 0.9 m and only 17 mm from the next 0.6 m. Between 0.9 and 1.5 m there remained 40 mm of available moisture (Figure 4).

Moisture conserved by fallow at Swift Current amounted to 92 to 101 mm as compared to 46 to 59 mm conserved in stubble according to Campbell, Zentner and Steppuhn (personal communication). They found that fallow conserved 33% of the precipitation in the first fall and winter and 10% of the precipitation in the next twelve months for an overall conservation of 17% of the precipitation in twenty-one months. A stubble field conserved from 26 to 34% of the precipitation that occurred in the fall and winter. These data were collected at Swift Current from 1967 to 1984 when average precipitation was 366 mm/yr. Staple and Lehane (1960) reported similar results for southwestern Saskatchewan. They found 33% of total precipitation was stored in a stubble field and 16% on a fallow field.

Christie et al (1985) reported that a Dark Brown Chernozem had accumulated 740 mm more water to 6 m than had an adjacent uncultivated prairie grassland after 54 years of cropping (Figure 5). They also found that a Brown Chernozem had accumulated 360 mm more water to 6 m than the grassland over a period of 46 years of cropping. This moisture amounts to 14 and 8 mm per year on the Dark Brown and the Brown soil respectively. This excess moisture found on cultivated land can contribute to saline seeps.

Figure 4. Extent of Water Depletion by Spring Wheat. Average of 102 trials in North Dakota 1958 to 1962.

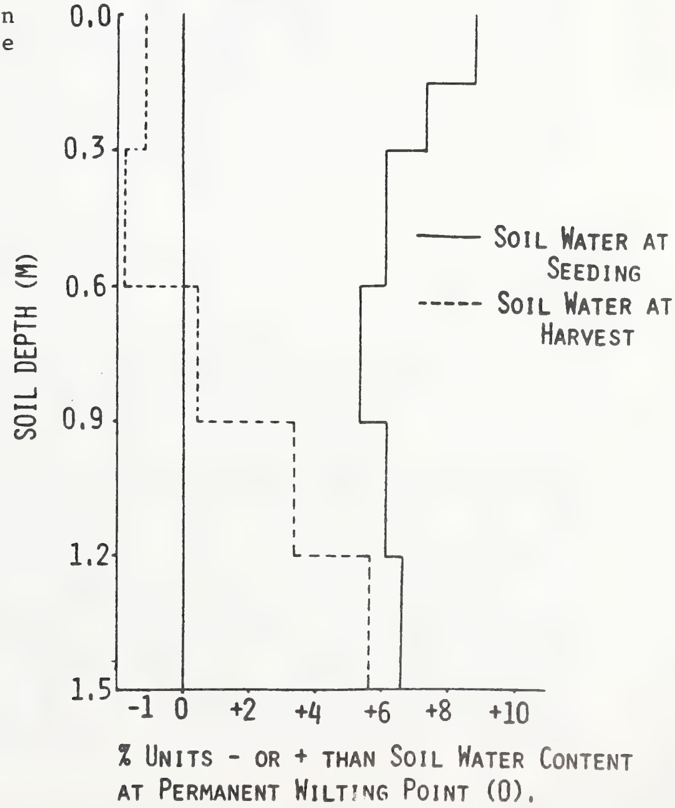
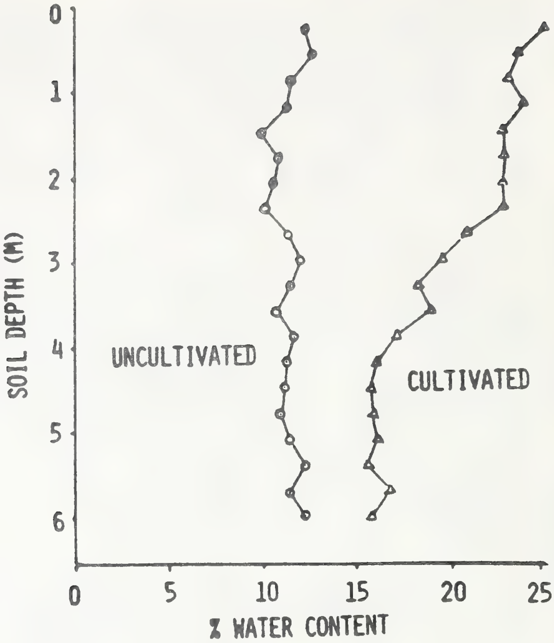


Figure 5. Soil moisture profiles for cultivated and uncultivated areas of a Dark Brown Chernozem.



Effects of Forages on Subsequent Wheat Yields

Kilcher and Heinrichs, 1966 and 1974 report yields for a variety of alfalfa grass mixtures at Swift Current and Tugaske when the mixtures were seeded onto land that had just grown cereals. Average annual forage yields were 2166, 987 and 672 kg/ha respectively for the first, second and next five years of the rotation. It appears that the high yields obtained in years 1 and 2 were because the crop is able to withdraw extra moisture from below 90 cm. Kilcher and Anderson, 1963 also note that a wheat fallow rotation following grass produced 154, 108 and 20 kg/ha less grain in each successive cycle of wheat than wheat in longer term wheat fallow rotation which included no grass. Kilcher attributes these lower yields to the more severe drying out of the soil by the grass crop. This emphasizes the limitations of using a mixed forage cereal rotation in the Brown soil zone.

Current wheat fallow systems are not using all the available moisture according to: 1) data from Swift Current on the storage of moisture by stubble and fallow; 2) Bauer's observation of unused moisture below 0.9 m; 3) Christie's evidence that a build up of moisture occurs on cropped land; and 4) Kilcher's records of high forage yields in the first two years in a grass alfalfa crop seeded on cereal land.

Recropping on Stubble

A question farmers face is: When are conditions suitable for recropping. Researchers do not agree on the usefulness of spring soil moisture in estimating the suitability of recropping stubble. Goos et al, 1984 reports on experiments carried out in Western North Dakota and concludes that available soil moisture (0-1.2 m depth) in the spring can be used to estimate the success of recropping (Table 3). For example, if the desired minimum yield on stubble is 1350 kg/ha and available soil moisture at planting is between 64 and 94 mm, the success of stubble recropping was uncertain. If soil moisture is above 94 mm, stubble recropping is advised while if below 64 mm, summerfallowing is recommended.

Campbell and Zentner based on data (unpublished) representing soil fertility trials in S.W. Saskatchewan have found: for fallow seeded crops in dry years with growing season rain less than 100 mm (4 inches) that wheat yield increased as the amount of available spring soil moisture increased (Figure 6). When stored available moisture on fallow was above 225 mm, additional stored moisture reduced the yield of wheat. For wheat grown on stubble in dry years each mm of stored soil moisture provided about 5.8 kg/ha of wheat (2.2 bushels/inch). For years with average or above average precipitation, stored soil moisture did not appreciably influence the yield of wheat grown on either fallow or stubble (Figure 6). Bauer and Young, 1966 had similar findings in North Dakota and reported that when rainfall was less than 150 mm (6 inches), yields increased with stored soil moisture. But when rainfall increased above 150 mm (6 inches), yields declined when stored soil moisture was above 150 mm.

Table 3. Stored available soil water in mm guidelines for recropping spring wheat in Western North Dakota.

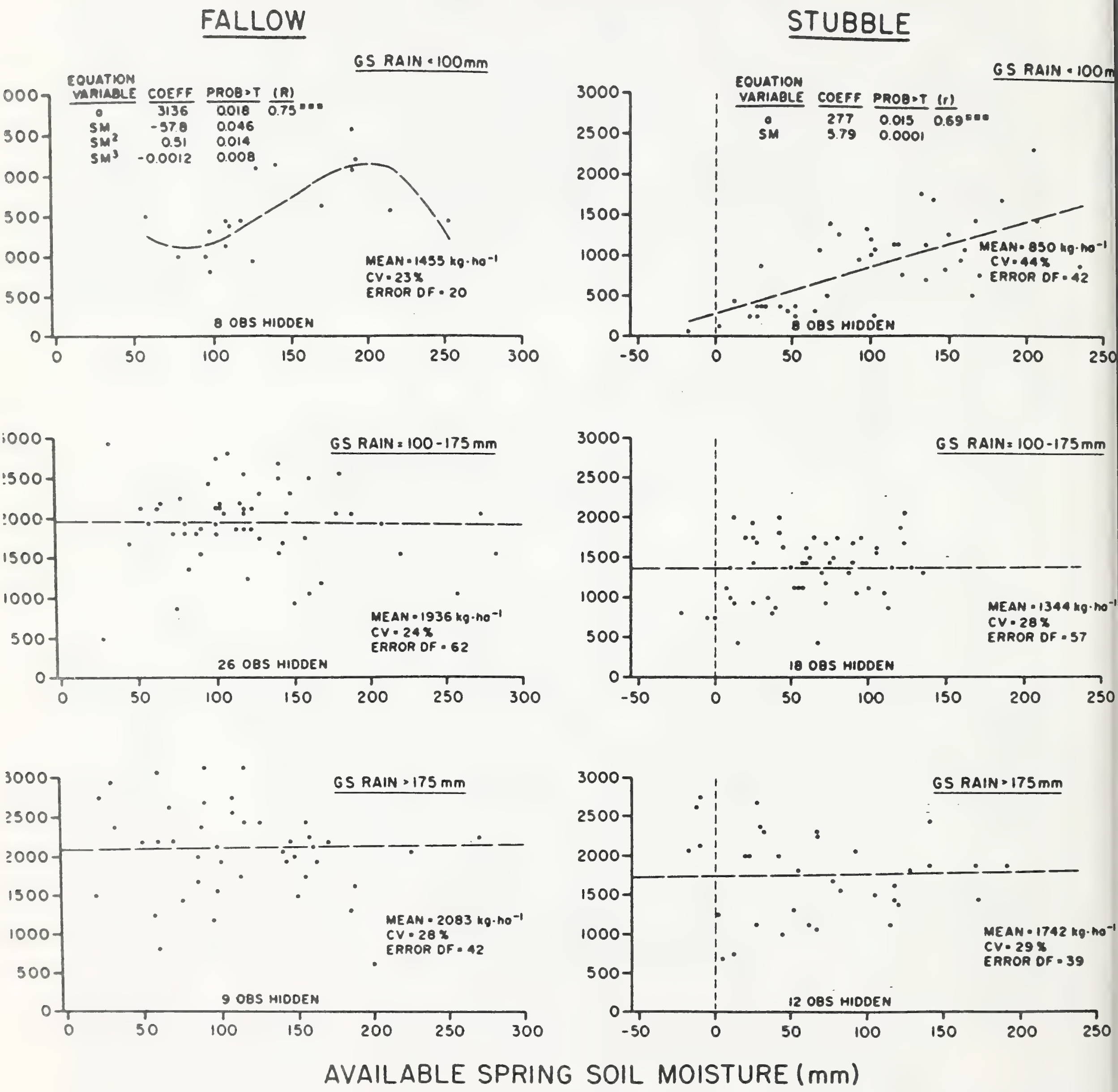
Minimum Acceptable Yield on Stubble kg/ha	Recommendation Soil Water in mm		
	Summerfallow	Uncertain	Recrop
1000	<53	53- 91	>91
1350	<64	64- 94	>94
1700	<71	71- 99	>99
2000	<76	76-102	>102

Less information on moisture storage and yield of fallow as compared to stubble has been collected in the moist areas of the prairies than in the Brown soils of Saskatchewan, North Dakota and Alberta. Michalyna and Hedlin, 1961, reported on the storage and use of moisture on fallow and stubble at Winnipeg, Manitoba. They found an average (over 3 years) of 18 mm more moisture stored on fallow than on stubble. They concluded that fallow contributed little additional water to the following crop. In contrast McKenzie and Clark (unpublished data) found with 3 site years of data from the Dark Brown soils of Central Alberta and 5 site years of data from Grey Luvisol or Black soils from the Peace River area that fallow in the spring contains an average of 45 mm more moisture than adjacent cropped sites (Table 4). In the more moist areas of the prairies the extra moisture present in the spring on fallow may not always be beneficial to the next crop.

Table 4. Average Difference of Accumulation of Ammonium and Nitrate Nitrogen and water for fallow as contrasted to stubble for 3 sites from Dark Brown soils of Central Alberta and 5 from Grey or Black soils of the Peace River.

Depth (m)	NH4-N kg/ha	NO3-N kg/ha	Water mm
0.0-0.9	2	64	31
0.9-1.5	-6	1	14

Figure 6. Effect of available spring soil moisture on yield of fallow and stubble wheat (available refers to water held at > - 1.5 Pa).



Relationships between Additional Water and Yield

The efficiency of the use of water by various rotations differ depending upon the way the calculation is made. Campbell, Zentner and Steppuhn, (personal communication), have provided examples from an eighteen year study at Swift Current of the water use efficiency of various rotations of hard wheat which were fertilized according to soil test recommendations. When efficiency is defined as grain yield/total moisture received during the harvest to harvest period, the fallow wheat rotation produces 2.6 kg/ha/mm as compared to 4.0 kg/ha/mm for the continuous wheat rotation (Figure 7). When efficiency is defined as the grain yield/spring soil moisture minus harvest soil moisture plus growing season precipitation, they calculated the following efficiencies. A fallow crop in a fallow wheat rotation produces 7.8 kg/ha/mm as compared to 6.5 kg/ha/mm produced by a continuous wheat rotation (Figure 8). In the first example using total precipitation a stubble crop was more efficient than crop seeded on fallow. In the second example based on moisture used by the crop the stubble seeded crop was less efficient than crop seeded on fallow. The first method penalizes the fallow crop rotation for its inefficiency of moisture conservation in the 20 month fallow period.

Figure 7. Moisture use efficiency of wheat at Swift Current as yield/precipitation for entire rotation.

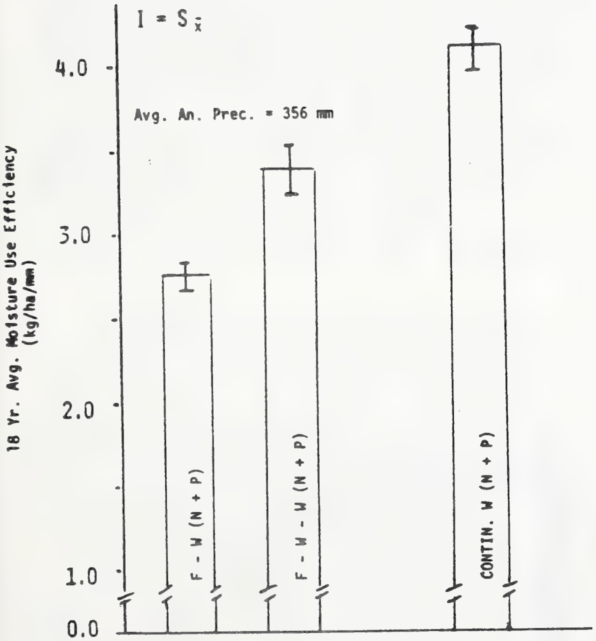
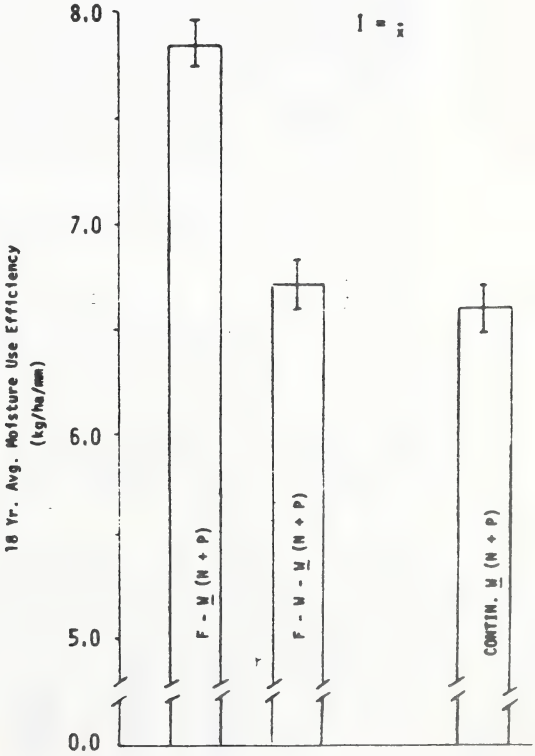


Figure 8. Moisture use efficiency of wheat at Swift Current as yield/(spring soil moisture - harvest soil moisture + growing season precipitation).



Water use efficiency increases as water use increases as long as water is received at times when there is a need for further moisture. At Brooks, Fielder soft white wheat was grown in a well fertilized, irrigated water use experiment (McKenzie and deSouza, 1985). Water use efficiency (according to the method of Figure 8) increased from 7.2 kg/ha/mm at a water use of 218 mm to 11.8 kg/ha/mm at a water use of 565 mm (Table 5).

Table 5. Water use efficiency in kg/ha/mm of Fielder soft wheat grown for three years at four levels of irrigation.

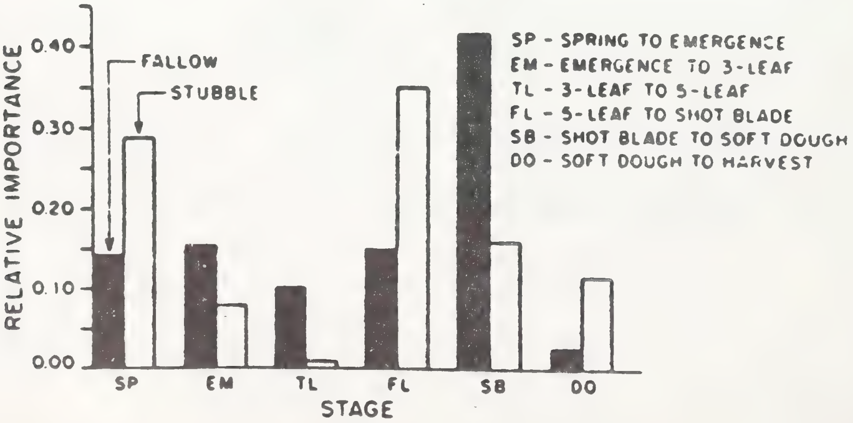
Water Use in mm	Grain t/ha	Grain Water Use kg/ha/mm	Total Dry Matter Water Use kg/ha/mm
218	1.58	7.2	15.1
331	2.97	9.0	19.0
409	3.99	9.7	19.5
565	6.69	11.8	24.7

Henry et al, 1986 developed a relationship of response of irrigated and dryland wheat to additional water based on data from Brooks and Outlook. Hard spring wheat would produce 10 kg/ha of grain per mm of water applied beyond a threshold level of 50 mm during the growing season. Fielder soft white spring wheat or HY320 3M wheat would produce 15 kg/ha of grain per mm of water beyond a threshold level of 75 mm.

Yields such as 7 t/ha (100 bu/acre) may be higher than it is feasible for most farmers to obtain. The trend to increasing efficiency with higher water use suggests that irrigation farmers and irrigation districts should try to provide water in such a manner as to strive for maximum economic yields.

Campbell and Zentner at Swift Current found rainfall was most important for stubble wheat in the spring prior to emergence and from the five leaf to the soft dough stage and for a fallow crop from the flowering stage to the soft dough stage (Figure 9). They also found that stored soil moisture and early growing season precipitation was important for stubble seeded crops to ensure proper stand establishment.

Figure 9. Growth periods of wheat at Swift Current when growing season precipitation is most critical to yields.



The Economic Value of Water

Zentner and Campbell at Swift Current developed curvilinear relationships between net farm income at the various product price levels and total available water (i.e., available stored soil moisture at time of planting plus growing season rainfall) for wheat grown on adequately fertilized fallow and stubble. They used the first derivative of these relationships to provide a measure of the economic value of an additional unit of water (Figure 10). The results show that the economic value of 1 mm of additional water decreased as the amount of total available water increased and as the price for wheat decreased. Further, the value of an additional unit of water was generally higher for wheat grown on stubble than for wheat grown on fallow. These results reflect the higher stored soil moisture that was available in fallow compared to stubble. At a wheat price of $147/t ($4.00/bu.) and assuming the mean total available water for fallow and stubble, the economic value of 1 mm of additional water averaged $0.47/ha for wheat grown on fallow and $0.92/ha for wheat grown in stubble ($4.80/acre/inch of additional water on fallow and $9.50/acre/inch on stubble). When the wheat price was $221/t ($6.00/bushel) the economic value of 1 mm additional water was $0.75 and $1.48/ha ($7.70 and $15.10/acre/inch) for wheat grown on fallow and stubble, respectively.

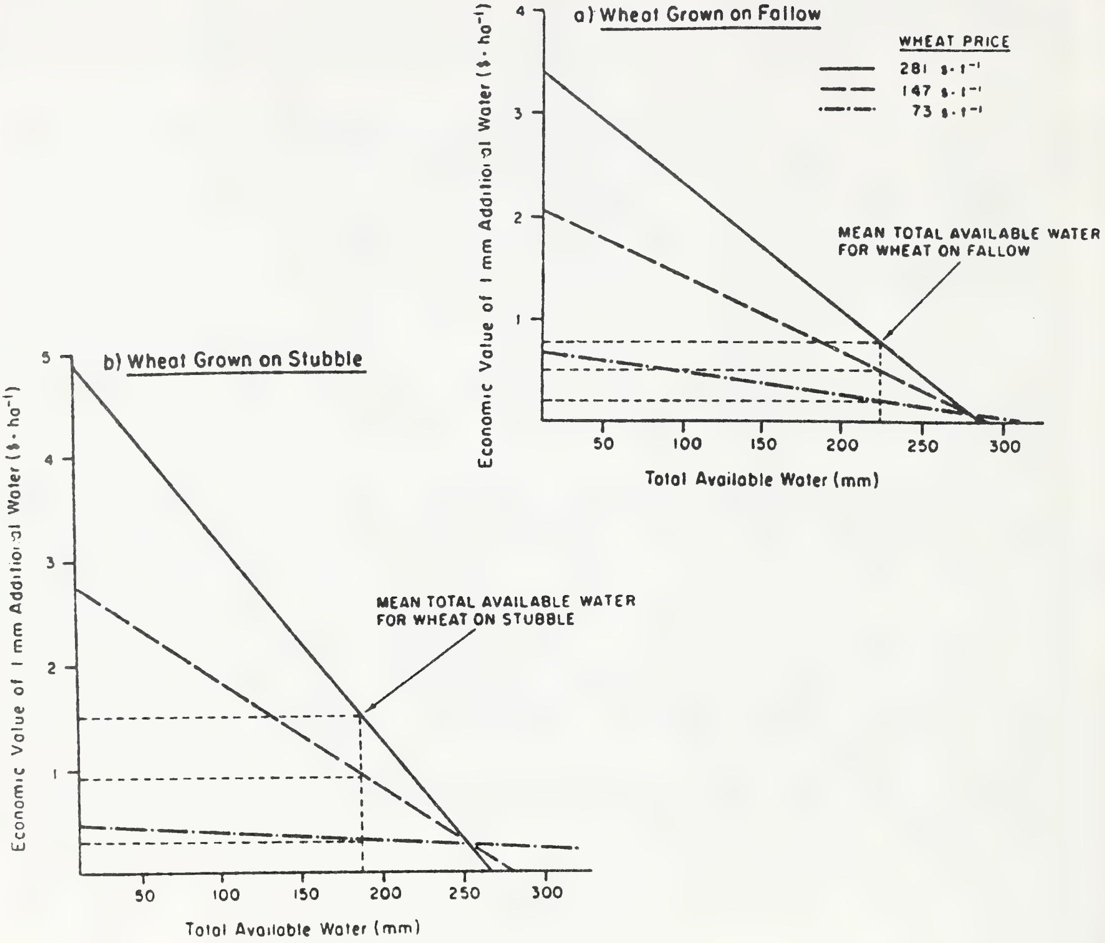
As the price of grain increases, the value of an additional unit of water is worth more on stubble than on fallow (Figure 10). The two examples from Swift Current shown in Figure 3 have no further benefits from water use above 255 mm and 285 mm for wheat seeded on stubble and fallow, respectively. The value of an additional increment of water at sites which receive more than 285 mm of available water should still be present as the system can be designed to make use of this water. Examples of a system which is designed to make use of more water than Swift Current is the example from irrigated wheat experiments (Figure 4) where maximum yield is obtained at a water use of 490 mm for hard wheat and 540 mm for soft and 3M wheats. This design would include higher yielding varieties, higher seeding and fertilizer rates, and better distribution of water throughout the growing season than what occurred at Swift Current.

SUMMARY

Drought is the major factor which limits crop production on the priaires. The carbon dioxide content of the air, the photosynthetic method of the plant, and the season all influence the efficiency of the crop's use of water. Plant breeders can select plant species for improved water use efficiency. Winter crops often have a more efficient use of water than spring crops. Millets, corn and kochia which are C4 crops use water more efficiently than C3 crops such as wheat, barley and alfalfa. The C4 crops require more heat than C3 crops, therefore the former are suited to the warmer areas of Western Canada.

The crop and the crop management system should be adapted to the anticipated moisture supply and economic conditions. This adaptation varies from a system at Swift Current where a stubble crop of hard wheat reaches its maximum yield at a water use of 255 mm to irrigated soft wheat at Brooks where the crop reaches its maximum yield at a water use of 540 mm. The efficiency of water use increases as the water use increases provided the crop and the crop management system are designed to accomodate the extra growth.

Figure 10. Economic value of 1 mm of additional water for wheat grown on fallow and stubble at Swift Current.



The farmer must consider both the short and long term benefits of the cropping system and rotation. Because of the likelihood of low grain prices in 1987, a fallow-wheat rotation may be the best short term alternative in the Brown soil zone. The slightly higher moisture supply and lower temperatures of the Dark Brown soil zone mean that a fallow-wheat-wheat rotation is the current best short term alternative. Not included in these costs are longer term soil productivity losses due to fallow such as declining organic matter and possible contribution of fallow to soil salinity or soil erosion. September of 1986 has provided record high precipitation in most of the Brown and Dark Brown soil zones of the Canadian Prairies. This should reduce the need for fallow in 1987, assuming grain prices and marketing opportunities do not deteriorate further. The long term choice of a rotation must include long term costs.

RECOMMENDATIONS

1. Research is needed to develop specialized crops and varieties which are selected for certain conditions:

    (1) high yield under limited moisture;
    (2) irrigated high intensity management;
    (3) winter cereals;
    (4) salinity tolerance;
    (5) acidity tolerance;
    (6) short season; and
    (7) water efficient metabolic pathways species such as corn, millets, kochia and pigweeds.

2. Improved information on the management of winter wheat and other winter crops.

3. Improved information for minimum tillage and moisture conservation farming.

4. More information is needed for planning the implications of long term climate change on agriculture: CO_2 changes; and temperature and precipitation changes.

5. To be most useful management practices should be studied and breeding programs should be conducted done in areas where drought is frequent. It is then easier to extend these practices to other areas where intermittent drought occurs.

6. Marketing opportunities need to be developed for winter wheat and 3M wheats. These wheats make more efficient use of water than hard spring wheat but present prices make it uneconomic to produce them.

7. Irrigation developments should be continued where feasible. Consideration should be given to improvement of efficiencies in irrigation supply, applications and management systems. For example, the Eastern Irrigation District is planning a demonstration project of a trickle irrigated pasture to improve the efficiency of its water use.

8. Roadways should be considered as a production resource and legislation should be developed to stop disposal of hazardous objects such as glass on roadsides. A 50¢ deposit on all glass bottles would reduce this problem.

9. Improvements in crop production techniques in much of Western Canada should revolve around improved water management and water use efficiences since water is the major factor limiting crop production in large areas of Western Canada.

10. Agriculture developments need to concentrate on programs such as the above that will maintain and improve the potential of agriculture. The maintenance and improvement of the soil as a water storage reservoir and crop production medium should be an essential part of the above programs. The cost and benefits of such soil maintenance and improvement programs may be longer range than the career of a farmer. This may require incentives to the farmer.

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FERTILIZER MANAGEMENT AND WATER USE EFFICIENCY[*]

D. M. MARANTZ [**]

ABSTRACT

Much research has examined the role fertilizer management plays in improving the water use efficiency of grain crops. Water use efficiency (ie.yield per unit water used)is enhanced by optimal fertilization, this results from significant increases in yield and under certain conditions is often accomplished without a noticeable increase in total water consumption. In the Western Canadian Prairies, cereal crops often depend upon a limited amount of moisture for the production of grain. The adequate nutrition of these crops is then a factor of major importance in the efficient use and conservation of water resources in these areas. The effects of fertilizer management on yields, total water use, and water use efficiency of cereal crops grown under dryland conditions, are summarized. Particular emphasis is on nitrogen fertilizer management. In addition, the yields of crops in these regions are as much affected by the timing and distribution of moisture as by the total amount which is made available. Therefore, the effects of timing of moisture on yields is also discussed. Research data from Manitoba, Saskatchewan and Alberta is used to illustrate the effects of fertilizer management on water use efficiency. The interaction between soil fertility and water availability is discussed in terms of fertilizer requirements for limited moisture conditions.

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FERTILIZER MANAGEMENT AND WATER USE EFFICIENCY IN LIMITED MOISTURE CONDITIONS

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1. INTRODUCTION

In semi-arid regions moisture is often the limiting factor to the production of cereal crops. In many areas of the Western Canadian Prairies, the amount of water required for maximum crop production during the growing season exceeds available moisture supplies. The efficient use of a limited amount of moisture is an important consideration in these areas and the methods of using moisture most efficiently has been the subject of a great deal of research. While other management practices may have a significant effect on the efficiency of water used, proper fertilizer management is among the most important. In addition to providing significant increases in the total marketable yield of cereal crops, fertilizer application may increase efficiency of water use without a significant increase in the total amount of water used.

The purpose of this paper is to provide documentation of the relationship between fertilizer management, total water use and water use efficiency of cereal crops grown under dryland moisture conditions. Although particular emphasis is placed on nitrogen fertilizer management, almost any fertilizer or fertilizer placement which increases yield without increasing total water use would have a similar effect.

In addition to fertilizer application, yields and water use efficiency are as much affected by the timing of moisture as by the total amount received. Therefore, the effects of timing of moisture availability are also discussed. The interaction between fertilizers and water availability is discussed in terms of fertilizer management decisions. For the most part, sources in Western Canada are referred to. However, a great deal of research has been carried out throughout the Great Plains region of North America and frequent reference will be made to some of this work.

2. BACKGROUND

Water use efficiency is described as the yield of plant product produced per unit water used by the crop:

$$\mathbf{WUE} = {}^{\text{yield}}/_{\text{total water use (ET)}}$$

Plant product may refer either to total drymatter yield or to total grain yield. Water used or evapotranspiration (ET) refers to the sums of water used by the crop during transpiration,

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lost from the soil by evaporation and that which is intercepted from rainfall or supplemental irrigation. Very simply, it is calculated as the change in soil moisture from seeding to harvest plus precipitation received during the growing season. It does not include or account for precipitation which is lost by runoff or the small amount of water used by the plant's metabolism (Power,1983)

Viets (1962), in the definitive review of the effects of fertilizers on water use efficiency, described six possible models relating yields to evapotranspiration when water was limiting, two of which were possible under field conditions. The first describes the possibility of fertilizers increasing both yield and total water use, the second describes fertilizers increasing yields without increasing total water use. In either case an increase in plant product or grain yield which results from fertilizer application generally occurs at a rate greater than the increase in total water use and in this way results in an increase in water use efficiency.

3. EFFECT OF FERTILIZERS ON TOTAL WATER USE AND WATER USE EFFICIENCY

A. SOIL MOISTURE EXTRACTION

Water use or evapotranspiration is regulated by the amount of water available, the demand of the atmosphere (e.g. temperature, wind, humidity) and by plant characteristics. The role fertilizers play in promoting changes in plant characteristics is well documented and is in part responsible for an alteration in the pattern of water use. Fertilization increases leaf area and leaf area duration of spring wheat, and results in a greater potential for increased water use through transpiration (Campbell et al. 1977). In addition, fertilization results in changes in plant rooting pattern and a consequent alteration in the pattern of soil water extraction.

A number of studies reporting the effects of fertilization on soil water extraction have assumed that the amount of soil moisture remaining after crop removal is similar among several fertilizer treatments. The assumption was made because it appeared that even the lowest fertilizer rates would result in crop removal of all available water (Anderson and Read, 1966). However, if plant rooting depth and density are increased by fertilization (Kmoch et al., 1957 ; Campbell et al., 1977) then the amount of water use should also be increased. When soil water is limiting, the ability of a well fertilized crop to develop an extensive root system and extract water to higher tensions and deeper depths than an unfertilized crop may significantly increase total water use (Viets 1963).

Warder et al. (1963) examined the influence of fertilizer application on moisture use by wheat on loam and clay soils of the Brown soil zone of Southwestern Saskatchewan. Their results showed that fertilized wheat used more moisture to 120 cm than nonfertilized wheat on the same soil type between seeding and heading time. However, total growing season water use for wheat on loam soils was the same for fertilized and check treatments. Fertilized trials on the clay soils extracted more subsoil moisture than unfertilized soils and as a result had higher total growing season water use values. The results suggest that a fertilized crop removes moisture to a greater extent than a crop not fertilized. However, in the drier regions of the prairies or on soils which have a lower water holding capacity (i.e. sandy soils), total growing season water use is similar because essentially all available moisture is used.

In Northern Alberta, the effects of increasing soil fertility on moisture use of barley on three Gray Luvisolic soils was examined (Hoyt and Rice, 1977). Soils of this type are generally found in areas of higher moisture and are unlike those found in the Brown soil zone. Field trials were carried out on fine sandy loam, loam and clay loam soils. Results showed an increase in moisture use for fertilized treatments at the 0-60 cm depth for soils in all three textural classes. However, moisture use (120 cm) increased in the coarser texture soils but not the clay loam where it appeared the penetration of roots to the deeper depths was restricted by the subsoil characteristics. For this study sufficient moisture was received and remained at harvest to ensure that moisture use differences between fertilizer treatments were shown. Differences in total water use not visible on the coarse textured soils in the brown soil zone were apparent in these areas because of higher moisture supplies.

Several other studies have examined the effects of fertilizer application on water use and soil water extraction by crops grown under limited moisture conditions. A number of these have been conducted in the Great Plains region of the United States. Bond et al. (1971) reported that nitrogen fertilization of a loam soil in North Dakota did not affect depth of soil water extraction by roots of spring wheat but rather increased water extraction from the same rooting depth. Brown (1971), working in Montana, also reported that nitrogen fertilization of loam soils increased water use of dryland winter wheat and that the greatest differences between fertilized and nonfertilized crops occurred in the 3 to 4 ft depth.

It should come as no surprise that fertilization, particularily with nitrogen fertilizer, may increase soil water extraction through its influence on plant characteristics and plant rooting patterns. The alteration of plant characteristics resulting from the application of fertilizers serves to increase total water use during the growing season and if enough water is available will result in a greater total growing season water use. In the drier regions of the prairies growing season water use may appear to be the same because all available soil water is depleted. This may not however, apply to regions outside the Brown and possibly the Dark Brown soil zone because of the greater amounts of availible moisture.

B. RELATIONSHIP BETWEEN YIELD AND TOTAL WATER USE

The results of 30 years of measurements of soil moisture and precipitation effects on wheat yields at Swift Current, Saskatchewan were summarized by Staple and Lehane (1954 a,b). Between 125 to 150 mm of total water use was required to produce the first kg/ha of wheat grain, and each additional mm of water use resulted in approximately 12 kg/ha of additional grain yield. de Jong and Rennie (1967), also working in Saskatchewan, suggested that 125 mm of total water use would result in a 600 kg/ha wheat crop.

Most recently, Campbell and Zentner (1987) examined the relationship between yield and moisture use of spring wheat for 17 years of accumulated data on a medium textured soil also in the Brown soil zone of Southwestern Saskatchewan. They reported that 80-90 mm are more likely values for the critical amount of moisture use needed to start producing yield than those reported earlier (Staple and Lehane, 1954; de Jong and Rennie, 1967) because of the nature of the expression used to describe the relationship between yield and available water. In their studies a quadratic relationship best described the response of wheat on a stubble seeded crop, while a cubic relationship best described response for a fallow seeded crop. The previous studies used linear functions to describe the relationship. The benefits of using a nonlinear function to describe the relationship will be discussed later.

A summary of yield-water use relations for spring wheat presented by Henry et al. (1986). On average, hard red spring wheat required 36-152 mm of total water use to produce the first kg of grain yield and responded with an average increase of 9.3 to13.2

kg/ha of grain for each additional mm of water use. The utility wheats (i.e. Glenlea) required 53 and 117 mm of water use to produce any yield and responded with 10.8 to 14.9 kg/ha for each additional mm (Table 1).

In Manitoba, Marantz and Racz (unpublished) examined the relationship between total water use and grain yield of wheat and barley. A total of twenty site years at ten different locations were combined to form the database (Table 2). Experimental sites were located on paired fallow and nonfallow fields. In general, fallow sites had higher total water use than nonfallow sites which was a reflection of the greater amounts of soil water available at seeding and the greater change in soil water content between seeding and harvest. Yields on fallow seeded sites were generally higher than stubble seeded crops fertilized with the same low rates of nitrogen.

Yields of both wheat and barley were significantly related to total water use ($p=.01$) when a quadratic relationship was used (Figure 1). The variation in yield data, although significantly related to water use, was observed over a number of nitrogen fertilizer application rates which served to increase yield at each level of total water use. For this reason, the amount of variation explained by the regression was not as high as would have been possible if measurements were made at a constant level of soil fertility. The relationship between soil fertility, moisture use and yields at these sites will be discussed later.

The amount of water use required for any grain production ranged from 11.0 cm for Conquest barley to 13.9 cm for Glenlea wheat (Table 3). The average for both wheat and barley was 12 cm. Each additional cm of total water use resulted in the production of between 340 and 464 kg of grain yield. These results are similar to those in the summary of data presented by Henry et al. (1986), although the increases in yield occured at a greater rate.

To summarize, yields of cereal crops grown in areas of limited moisture are significantly related to evapotranspiration. Cereal crops require on average 12 cm of total water use to produce the first kg of grain and respond with an additional 10 to 40 kg /ha of grain per mm water used. The nonlinear term used to describe the relationship between yield and total water use has the advantage of describing a maximum yield beyond which further increases in total water use result in minimal or no further increases in yields; a situation which is more realistic than one described by linear function. The occurence of a maximum yield, which favors the nonlinear relationship, was the result of leaching of nitrates or possibly denitrification occuring at high levels of available moisture (Campbell et al., 1987). In most cases, the benefits of additional moisture will not be realized if nutrients become limiting at the higher levels of available moisture (Tisdale et al., 1985).

C. EFFECT OF FERTILIZER ON WATER USE EFFICIENCY

Crop response to water is often expressed as weight of grain produced per unit water used and referred to as water use efficiency. The addition of fertilizer has been shown to increase yield at a rate greater than the consumption of water and results in an increase in the efficiency of water used. Fertilizer management is an important aspect in the efficient use of a limited amount of moisture available for crop production on the prairies. However, fertilization is a reasonable method of improving water use efficiency only if an economically feasible rate of fertilizer is applied (Viets, 1963) and the application does not result in a decrease in yield (Bond et al., 1971).

The improvement in water use efficiency of grain crops with improved soil fertility has been documented for some time now. Montgomery and Kisselbach (1912) stated that the fertility of the soil had a "pronounced" influence on the water requirement of corn. They reported having greater vegetative production of corn per inch water use in a fertile soil than in one which was considered infertile. An enhancement in water utilization with the addition of manure was also reported.

In Nebraska (Olson et al., 1964) reported that judicious fertilizer use resulted in an average increase in water use efficiency of 29% among several different grain crops and that increases occured almost in proportion to the yield response to fertilizer. In this study, increases in water use efficiencies for individual treatments with nitrogen fertilizer were as high as 100%. Working in Montana, Brown (1971) reported that the application of nitrogen fertilizer to dryland winter wheat increased both grain yields and total water use. Furthermore, water use efficiency was increased an average of 56% with the application of nitrogen.

Ramig and Rhoades (1961) demonstrated that water use efficiency of winter wheat increased as available moisture at seeding and nitrogen fertilization increased. However, when moisture supply at seeding was low and the application of nitrogen high, the production of the vegetative portion of the crop was favoured and resulted in an exhaustion of the water supply to the point where insufficient water remained to produce grain. The reduction in grain yield which occured implied that use of available water was not efficient and resulted in a subsequent decline in the calculated value for water use efficiency.

In Manitoba, the increase in water use efficiency with the addition of fertilizer nitrogen was examined for two varieties each of wheat and barley (D.M.Marantz and G.J Racz, unpublished). Fertilizer nitrogen was applied at seven rates prior to seeding on both fallow and nonfallow sites at ten locations in Southern Manitoba. Soil moisture measurements were taken at both seeding and harvest. Growing season precipitation was recorded at each location. Total water use was calculated as the change in soil moisture content from seeding to harvest (120 cm) plus moisture received from growing season precipitation (table 2). Harvest soil moisture was measured as an average of all nitrogen fertilizer treatments which may have resulted in an overestimation of soil moisture remaining in the heavily fertilized treatments and an underestimation of moisture remaining in the treatments with low rates of applied fertilizer.

Fertilizer nitrogen increased water use efficiency an average of 36% on nonfallow sites and 12% on fallow sites. Water use efficiency on fallow fields showed limited response to fertilizer because of initially high soil nitrogen levels. The highest water use efficiencies recorded were for Fergus barley (119 kg/ha/cm), the lowest for Neepawa wheat (53 kg/ha/cm) both grown on nonfallow fields (Table 4). Water use efficiencies of 70 to 120 kg/ha/cm were recorded in Saskatchewan by Staple and Lehane (1954 a,b) for spring wheat. Kachanowski et al. (1985) reported water use efficiencies of spring wheat from 100 to 270 kg/ha/cm also for spring wheat in Saskatchewan.

In Northern Alberta, Hoyt and Rice (1977) examined the effects of higher levels of soil fertility on water use efficiency of barley. The addition of chemical fertilizers to three Gray Luvisolic soils of three different textures resulted in increases in water use efficiencies of almost threefold. The highest values for water use efficiency occured on coarsest textured soils (fine sandy loam) and decreased as the soils became heavier in texture. In general, water use efficiencies were highest where yields were the highest (table 5).

Winter wheat has been suggested to be a more efficient user of water because of differences in growth habit (de Jong and Steppun, 1983). Field experiments conducted in

Saskatchewan by Entz et al. (1986) confirmed that under dryland conditions, the water use efficiencies of winter wheat were as high as 282 kg/ha/cm and averaged over 192 kg/ha/cm. Water use efficiency under irrigation was less than under dryland conditions for the experiments with winter wheat, the result of a limitation from fertility under irrigated conditions. In their experiments, the amount of variation in dryland winter wheat yields explained by total water use was increased when sites high in soil nitrogen were not used, suggesting that yields were significantly affected by both fertility and moisture (figure 2).

In summary, nitrogen fertilizer management appears to play a significant role in the improvement of water use efficiencies under dryland conditions. The improvement in water use efficiency appears to be most related to yield increases which occur with addition of fertilizer. The increase in total water use which occurs with higher fertility occurs at a rate less than the increase in yield and as a result water use efficiency continues to increase. Increases in total water use with the addition of nitrogen fertilizer has seldom exceeded 25% whereas yield response to applied nitrogen fertilizer may be as high as threefold.

Accelerated water use through excessive early season fertilization may limit water use efficiencies through the early depletion of available water and favored the production of vegetative material. Winter wheat has been shown to be a particularily efficient user of water because of its ability to use early season available moisture when temperatures are low and because of its response to fertilizer application.

4. TIMING AND DISTRIBUTION OF MOISTURE AND THE EFFECTS ON WATER USE

In the cycle of a plant's development, certain periods are more sensitive to water limitations than others. If during these periods fertilizers can increase growth without depleting water at a greater rate then total yield and water use efficiency can be increased. On the other hand, if fertilizers increase growth and water use, then the yield potential and water use efficiency will depend on the total water supply available and the development of the crop at the time. In areas of limited moisture supply, accelerated water use through fertilization will significantly reduce the yield of grain if moisture is not available at the time when grain is filling.

It is a long recognized fact that the effect of water on grain yield of cereal crops is highly dependant on the stage of growth when water is received or water stress occurs. Mack and Ferguson (1978) found that yields were most seriously affected by a moisture stress applied at the 5th leaf to soft dough stage. They also found that yields were affected much less by moisture stress applied at the soft dough to ripe stage. Baier and Robertson (1968) found that moisture stress during the planting to jointing stage had very little effect on the final grain yield.

Several studies have examined the effect of water availability and fertilization on water use at different growth stages of cereal crops. Brown (1971) working in Montana examined the cumulative water use by winter wheat with three rates of nitrogen fertilizer. Daily water use increased as the season progressed and reached maximum values during the heading to flowering stage. Wheat seeded on a check site reached maximum daily water use earlier than wheat seeded on the fertilized sites.

In Saskatchewan, Henry and Hogg (1977) found that the timing of irrigation treatments had a significant effect in preventing yield reductions due to moisture stress at critical stages of crop development. They observed the effects of four water treatments at different times, determined by soil moisture measurements, and six rates of nitrogen fertilizer on the grain yield of three wheats (Sinton, Fielder and Glenlea). With little or no moisture stress the response of each wheat was significantly increased with the addition of nitrogen fertilizer and moisture stress applied early in the growing season reduced the response to nitrogen more than stress applied later in the season. Furthermore, yield data indicated that irrigation treatments omitted at the early jointing to heading stage resulted in the largest yield reductions.

The timing of precipitation has a significant influence on the grain yields of cereal crops grown in western Canada. Precipitation received during grain develpoment is generally reported to be most important with respect to final grain yields (Figure 3). This confirms the findings of Bauer (1972) and corresponds to the period when moisture use is greatest (Brown , 1971). Campbell and Zentner however, reported that for stubble seeded crops in Swift Current Saskatchewan, precipitation received at seeding was just as important to final grain yields as that which was received at the time of grain development. On fallow sites, precipitation received at seeding was less important than that which came later in the growing season when soil moisture was depleted on the fallow seeded sites.

Where moisture is limited, the timing of nitrogen fertilization may also have a significant effect on grain yields (Loomis,1983) by its influence on water use. Early applications of fertilizer may expand ground cover during the vegetative phase and use more stored soil moisture, and if moisture is not available a significant reduction in grain yields can occur. In contrast, nitrogen fertilization after flowering may have favorable effects, such as increasing access to stored soil moisture at a critical time and delaying the senescence of older plant leaves. Late applications of fertilizer may also serve to significantly improve water use efficiency.

The above discussion shows the importance of having moisture available during the critical periods of plant development, specifically during grain filling. The importance of proper fertilizer management is highlighted by the risk of over fertilization and the possibility of early season depletion of moisture, leaving little available for grain production. The timting of precipitation is critical to grain development, which is more evident on stubble seeded crops than on fallow seeded crops, because of differences which exist in soil moisture at seeding time. The effects of late season fertilizer application may prove beneficial with respect to water utilization at critical periods.

5. PREDICTING YIELD FROM WATER USE AND APPLIED FERTILIZER

There is a strong interaction between water use and response to applied fertilizers in the Western Canadian prairies. A complete review on the interaction between nitrogen fertilizer and moisture was presented by Henry et al. (1986). The effect of fertilizer on improving water use efficiency of grain crops was documented above. However, the improvement in water use efficiency is only of value if the fertilizer applications make economic sense. The challenge then becomes to predict fertilizer application rates which will make the most efficient use of a limited amount of moisture. The best way to do this would be to predict yield based on total water use or available moisture and fertilizer applications.

Much of the soil fertility research conducted in the past decade has focused on the yield reductions caused by nutrient deficiencies and the correction of the deficiencies by fertilizer applications. The same concept may be applied to moisture deficits and the combination of nutrient and moisture deficits. Power (1971) examined the yield reductions which occured in smooth bromegrass under moisture and nutrient deficits. The yield reductions arising from nitrogen and water deficits were additive and amounted to a total yield reduction of 54%.

In many regions of Western Canada total water use is seldom as high as potential evapotranspiration, leaving a significant deficit in moisture. To illustrate this, mean monthly pan evaporation for the summer months at Lethbridge, Alberta is shown in figure 4 from Shaykewich et al. (1986). For the summer months, evaporation was far in excess of average precipitation, the difference between the two representing the moisture deficit. Yield reductions arising from moisture deficits in these areas are significant. Figure 5 shows moisture deficits mapped out for Western Canada. As expected, the highest deficits occur in the regions of lowest rainfall and highest temperatures, in particular the brown soil zone of Western Canada.

In Manitoba, Marantz and Racz (unpublised data) examined the influence of moisture deficits and nitrogen fertilizer applications on the yield of two varieties each of wheat and barley. Moisture deficits were described as the difference between total water used and a calculated potential water use (Figure 6). Yield reductions arising from moisture deficits occured at an average rate of 75 kg/ha/cm. The relationship between moisture deficits and yields was observed over a number of nitrogen fertilizer application rates. Therefore, the relationship was less clearly expressed because of the ablility of nitrogen fertilizer to increase yields at each moisture deficit. The additive effects of moisture deficits and nitrogen fertility on explaining yield variation are shown in table 6 also from Marantz and Racz. With this information and mapped moisture deficits such as those in figure 5, the potential exists for estimating nitrogen fertilizer responses in regions of characteristic moisture deficits.

In Southern Alberta, Bole and Pittman (1980) used field trials to develop yield response functions for barley using nitrogen fertility, available soil moisture and precipitation as variables. In their experiments, yield of barley was highly dependant on stored soil water, growing season precipitation and nitrogen fertilizer. These variables accounted for 89% of the variation in yield. Furthermore, the authors reported that for the mean soil water and precipitation values used in the study, stored soil water increased yield 9.8 kg/ha/mm while growing season precipitation increased yield a total of 6.5 kg/ha/mm without ferilizer added. These increases were however only 19% and 52% of those which occured with 90 kg/ha nitrogen fertilizer added.

With equations such as those developed by Bole and Pittman, nitrogen fertilizer requirements may be adjusted with respect to stored soil water at seeding and the probability of receiving a given amount of precipitation. In this way, the most efficient use of a limited amount of water may be made as well as the most efficient use of the fertilizer nitrogen applied.

6. SUMMARY

1. Fertilizer nitrogen increases root weight and density of cereal crops and results in the increased extraction of moisture both from the same depth as nonfertilized crops and from deeper depths. Although crops grown in the drier regions of the prairies remove essentially all available moisture, outside these areas fertilizer nitrogen may increase total growing season water use. The increased ability to access available moisture is one reason for the improved water use efficiency of fertilized crops.

2. Grain yields of cereal crops in Western Canada are significantly related to total water use or evapotranspiration. On average wheat and barley require approximately 12 cm of total water use to produce the first kg of grain and then respond with an additional 10 to 40 kg/ha of grain yield for every additional mm of total water use.

3. Fertilizer application increases water use efficiency mainly through significant increases in grain yield that occur at rates greater than increases in total water consumption. Total water use may increase up to 25% with the addition of nitrogen fertilizer, while yields may increase two to threefold.

4. Maximum water use by cereal crops occurs at the heading stage which is the critical time when final grain yield is decided. Therefore, the timing of moisture availability may be equally important as the total amount made available. Excessive fertilization at early stages of plant development may lead to early season depletion of available moisture, leaving little for the critical period at grain filling.

5. Late season fertilizer applications may have the potential to increase water use efficiency by increasing the plants ability to extract available moisture at the most critical time of crop development.

6. The ability to estimate yield based on total water use and applied fertilizers allows fertilizer application rates to be adjusted such that available and potential water as well as fertilizers are used most efficiently.

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TABLE 1. THE EFFECT OF WATER USE ON THE GRAIN YIELD OF WHEAT*

MARKET CLASS	VARIETY	REGRESSION EQUATION	R	kg/ha per mm	WU for 0 Yield mm	Years	Location	Source
HRS [1]	(various)	Y=1831 + 13.2 WU	0.78	13.2	139	1925-52	Swift Current, Sask.	Staple and Lehane, 1954b [2]
HRS [1]	(various)	Y=1759 + 11.6 WU	0.78	11.6	152	1925-52	Swift Current, Sask.	Staple and Lehane, 1954b [3]
HRS [1]	Sinton	Y=-954 + 10.6 WU	0.94	10.6	90	1977-79	Outlook, Sask.	Henry, J.L., unpub. data
HRS [1]	Neepawa	Y=-335 + 9.3 WU	0.90	9.3	36	1981-85	Brooks, Alta.	McKenzie, R.C., unpub. data
SWS [5]	Fielder	Y=1259 + 10.8 WU	0.49	10.8	117	1977-79	Outlook, Sask.	Henry, J.L., unpub. data
SWS [5]	Fielder	Y=769 + 14.5 WU	0.88	14.5	53	1981-85	Brooks, Alta.	McKenzie, R.C., unpub. data
Utility	Glenlea	Y=1317 + 11.7 WU	0.90	11.7	113	1977-79	Outlook, Sask.	Henry, J.L., unpub. data
3M	HY320	Y=1237 + 14.9 WU	0.86	14.9	83	1983-85	Brooks, Alta.	McKenzie, R.C., unpub. data

Y = Grain yield (kg/ha)
HRS = Hard Red Spring
Data from tanks
Data from field plots
SWS = Soft White Spring
*Data reproduced from Henry et al., (1986)

TABLE 2. GROWING SEASON PRECIPITATION, CHANGE IN WATER CONTENT AND TOTAL WATER USE FOR EXPERIMENTAL SITES IN SOUTHERN MANITOBA (1972-1975)

STATION	YEAR	CHANGE IN WATER CONTENT (120 cm)		G.S.P. (cm)**	TOTAL WATER USE (cm)+	
		Non Fallow*	Fallow*		Non Fallow	Fallow
Birtle	1972	8.9	17.8	17.3	26.3	35.1
	1973	13.9	18.9	16.2	30.1	35.1
	1974	11.6	14.6	14.0	25.6	28.6
Brandon	1975	10.1	13.2	29.9	39.9	43.1
Glenboro	1972	4.3	10.9	23.2	27.4	34.0
	1973	6.2	10.7	23.3	29.5	34.0
	1974	9.3	15.7	22.8	32.2	38.5
Goodlands	1972	6.9	14.7	23.9	30.9	38.7
	1973	6.2	10.7	23.3	29.5	34.0
	1975	9.3	15.7	22.8	32.2	38.5
Hamiota	1975	13.2	16.0	17.5	30.8	33.6
Morris	1972	10.9	18.0	20.1	31.0	38.1
	1973	12.9	20.8	24.7	37.7	45.5
Pilot Mound	1972	15.8	20.8	21.5	37.3	42.3
	1973	10.9	22.2	21.7	32.6	43.9
	1974	13.9	22.6	10.0	23.9	33.6
	1975	25.3	25.3	20.6	45.9	45.9
Portage	1972	8.9	9.0	13.6	22.5	22.7
	1973	11.4	8.9	29.5	41.0	38.3
Roland	1975	12.8	26.2	18.2	31.1	44.5

+ Total water use = water content + growing season precipitation

* Average NO_3-N to 60 cm for fallow 70 kg/ha for non fallow 27 kg/ha

** Growing Season Precipitation

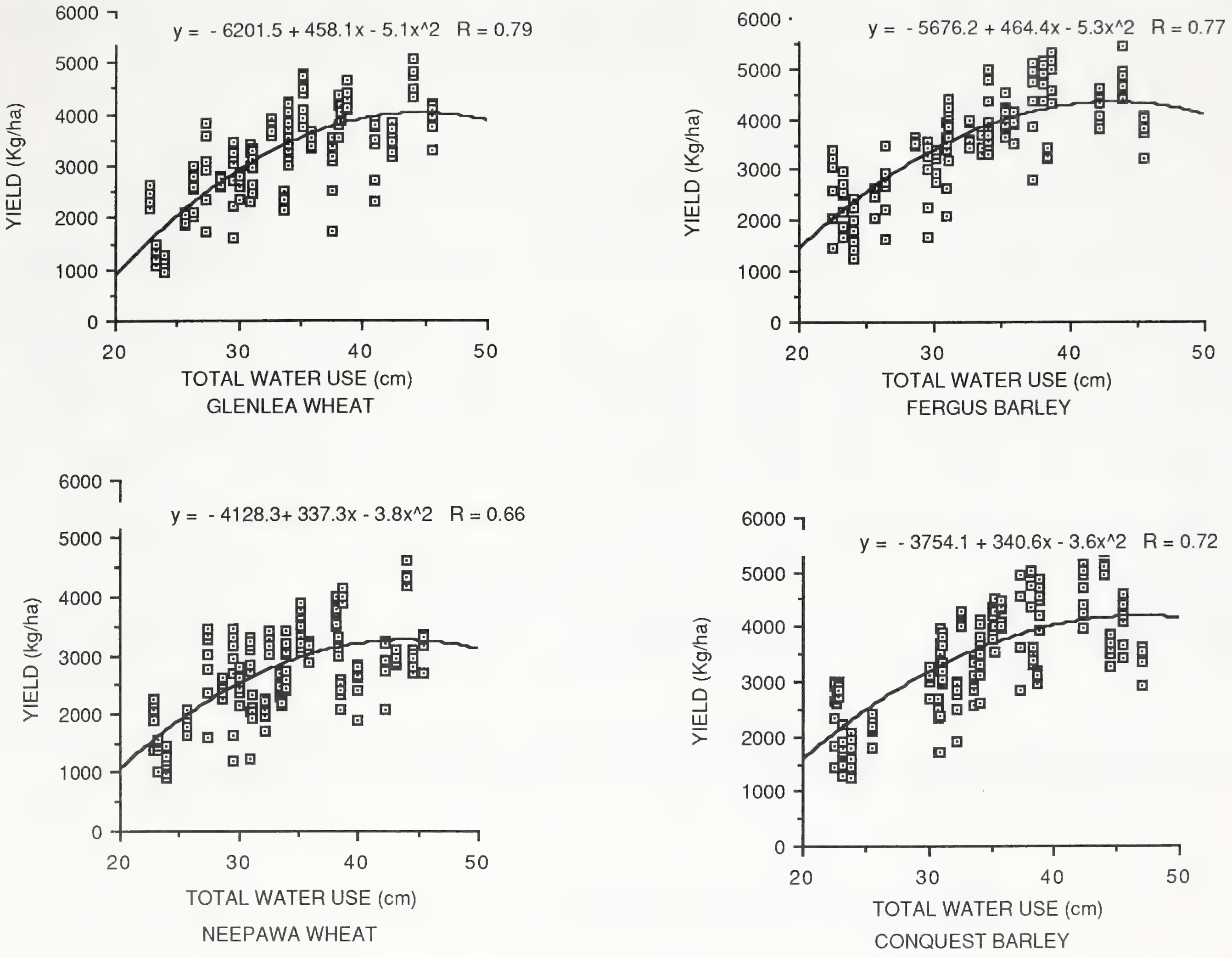


Figure 1. The effect of total water use (evapotranspiration) on the yield of four cereal crops in Southern Manitoba (1972-1975)

TABLE 3. REGRESSION EQUATIONS SHOWING THE EFFECTS OF TOTAL WATER USE AND MAXIMUM WATER USE AT ZERO YIELD FOR 4 CROPS IN SOUTHERN MANITOBA (1972-1975)

CROP	VARIETY	NO. OF SITE YEARS	REGRESSION EQUATION	R	MAXIMUM WATER USE AT ZERO YIELD
WHEAT	NEEPAWA	40	$Y=-4128.3 + 337x - 3.8x^2$	0.66	12.2
WHEAT	GLENLEA	30	$Y=-6201.5 + 445x - 5.1x^2$	0.79	13.9
BARLEY	CONQUEST	40	$Y=-3754.1 + 340x - 5.3x^2$	0.72	11.0
BARLEY	CONQUEST	30	$Y=-5676.2 + 464x - 5.3x^2$	0.77	12.3

x = Water use (cu)
y = Yield (kg/ha)

TABLE 4. TOTAL WATER USE AND WATER USE EFFICIENCY AS AFFECTED BY ADDED NITROGEN FERTILIZER FOR FOUR CROPS IN SOUTHERN MANITOBA (1972-1975)

				RATES OF NITROGEN (kg/ha)*						
CROP	VARIETY	NO. OF SITE YEARS	TOTAL WATER USE (cm)+	9	34	67	101	134	202	269
				WATER USE EFFICIENCY (kg grain/cm/ha)						
				Non Fallow						
BARLEY	FERGUS	15	27.8	70.1	86.2	102.9	110.3	115.0	119.3	117.3
BARLEY	CONQUEST	20	31.7	66.1	77.0	92.3	98.5	104.0	110.1	108.2
WHEAT	GLENLEA	15	27.8	63.4	74.1	87.8	89.3	94.9	97.9	97.9
WHEAT	NEEPAWA	20	31.7	52.5	65.9	76.2	82.0	85.7	86.0	88.3
				Fallow						
BARLEY	FERGUS	15	35.2	110.2	113.0	117.0	118.1	118.9	116.7	117.3
BARLEY	CONQUEST	20	36.7	92.0	97.8	101.9	104.8	107.1	107.0	105.0
WHEAT	GLENLEA	15	35.2	100.1	101.1	104.7	105.1	106.6	106.8	108.9
WHEAT	NEEPAWA	20	36.7	78.1	81.5	82.8	84.4	84.0	85.3	85.0

+ Total water used (soil moisture spring -- soil moisture fall) + Growing Season Precipitation

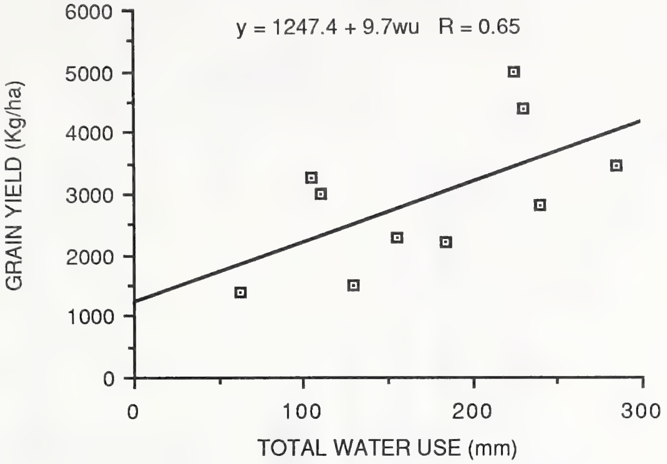
* Water use efficiency = total grain yield/total water used

TABLE 5. EFFICIENCY OF WATER USE BY BARLEY ON THREE LUVISOLIC SOILS RECEIVING CHEMICAL FERTILIZER (AVERAGE OF 5 YEARS, 1967-1971)

	kg of Barley/cm Water Used	
SOIL TYPE	NO FERTILIZER	CHEMICAL FERTILIZER
Fine Sandy Loam	94	188
Loam	65	154
Clay Loam	53	138

Data reproduced from Hoyt and Rice (1977)

A.



B.

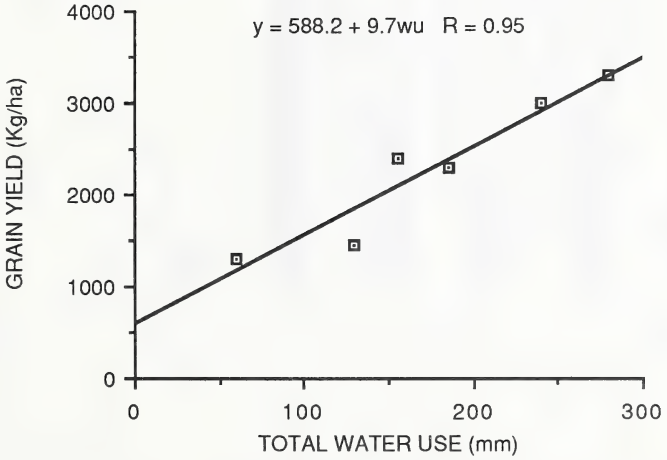


Figure 2. The effect of total water use (evapotranspiration) on the yield of winter wheat in Saskatchewan (from Entz et al., 1986)

A. High soil nitrogen sites included

B. High soil nitrogen sites removed

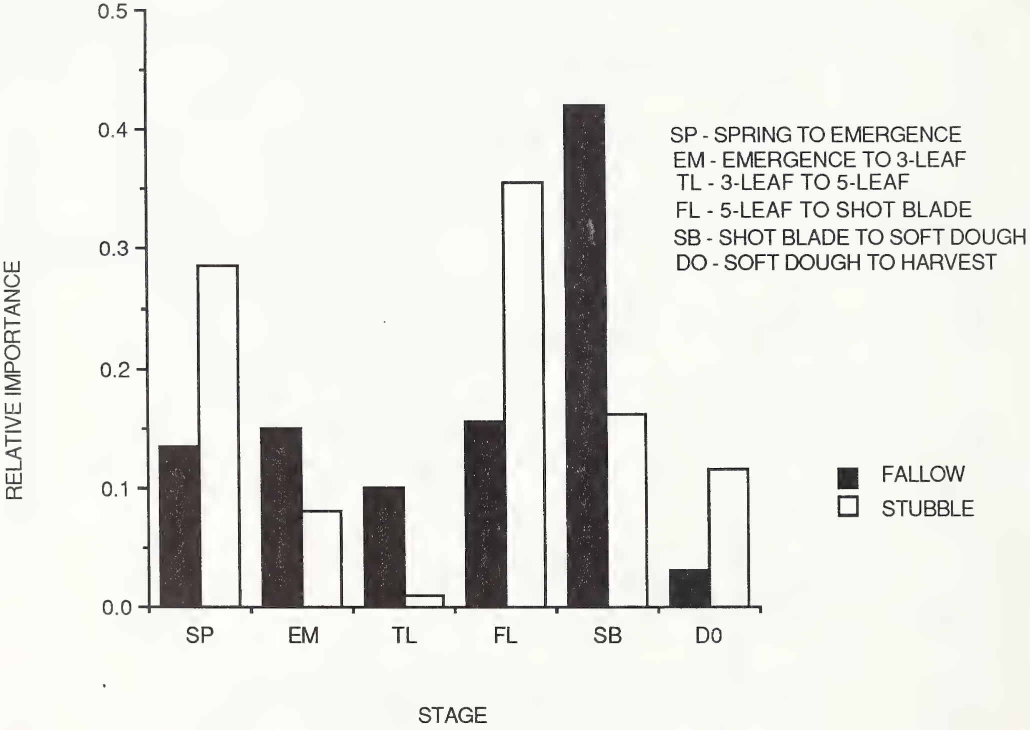


Figure 3. Growth periods when GSP is most critical to yields.

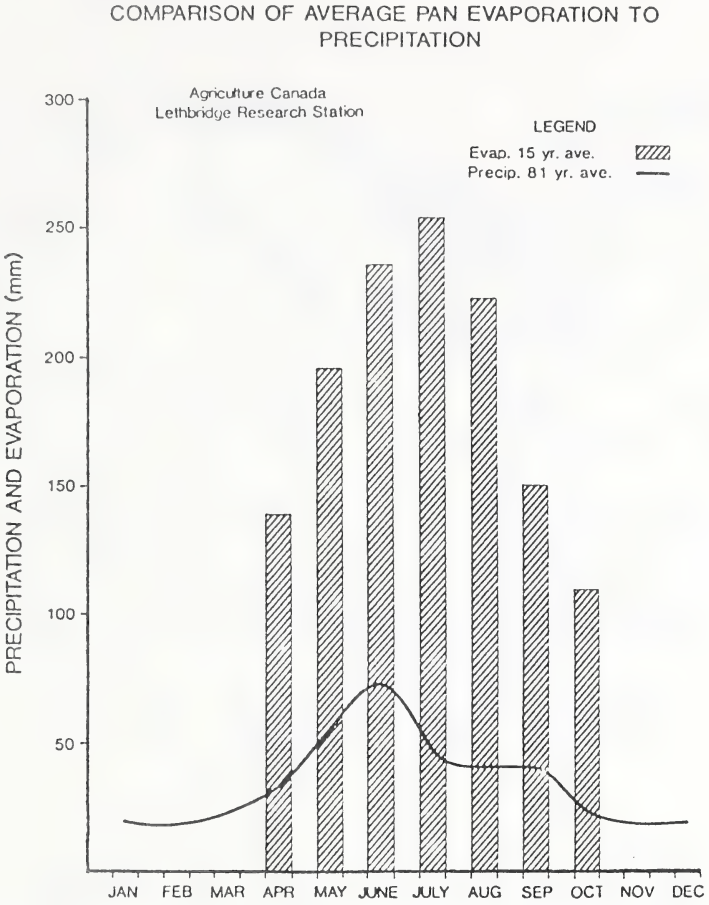


Figure 4. Comparison of average pan evaporation (15 yr average) to precipitation (81 yr average) at Lethbridge, Alberta .

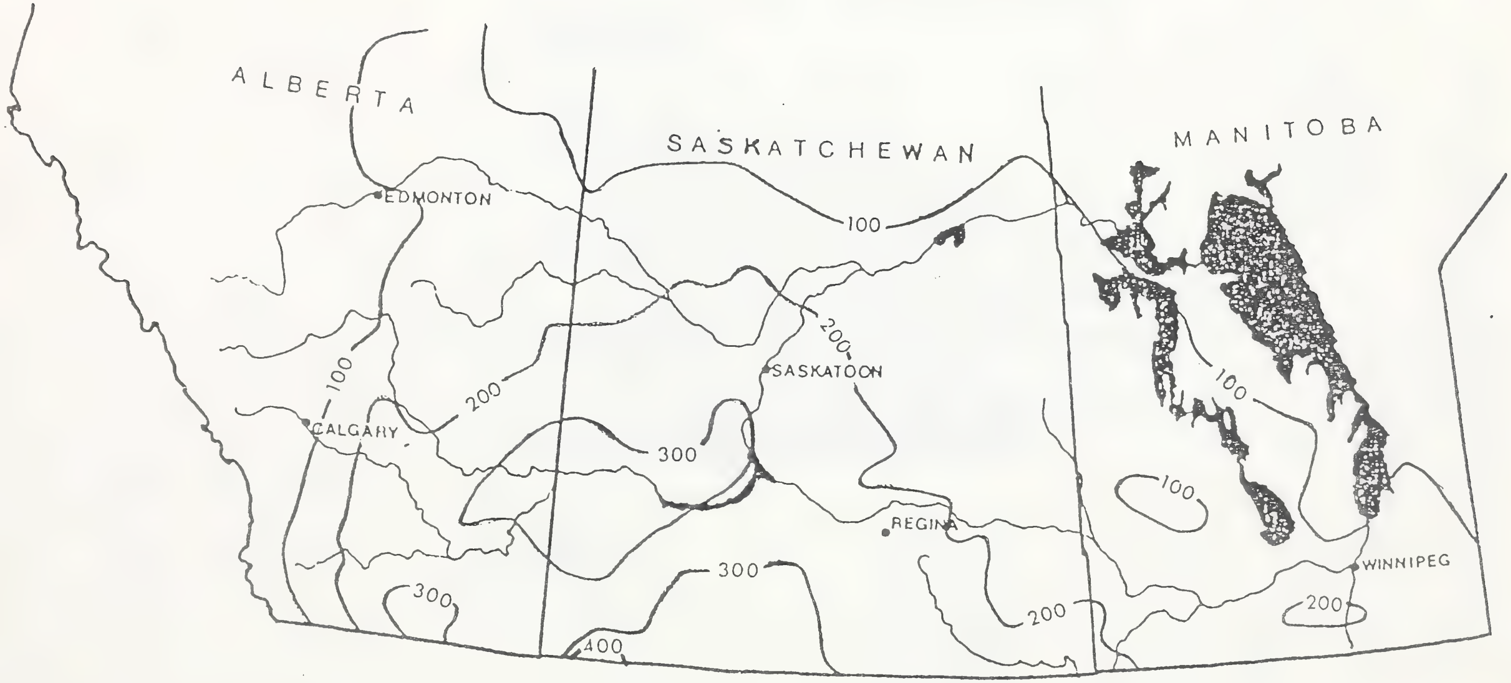

ALBERTA
SASKATCHEWAN
MANITOBA
EDMONTON
CALGARY
SASKATOON
REGINA
WINNIPEG
100
100
100
100
200
200
200
200
300
300
300
400

Figure 5. Average soil water deficit (mm) (potential evapotranspiration - Precipitation) for the Prairie Provinces in Western Canada. (Reproduced from Shaykewich et al., 1986)

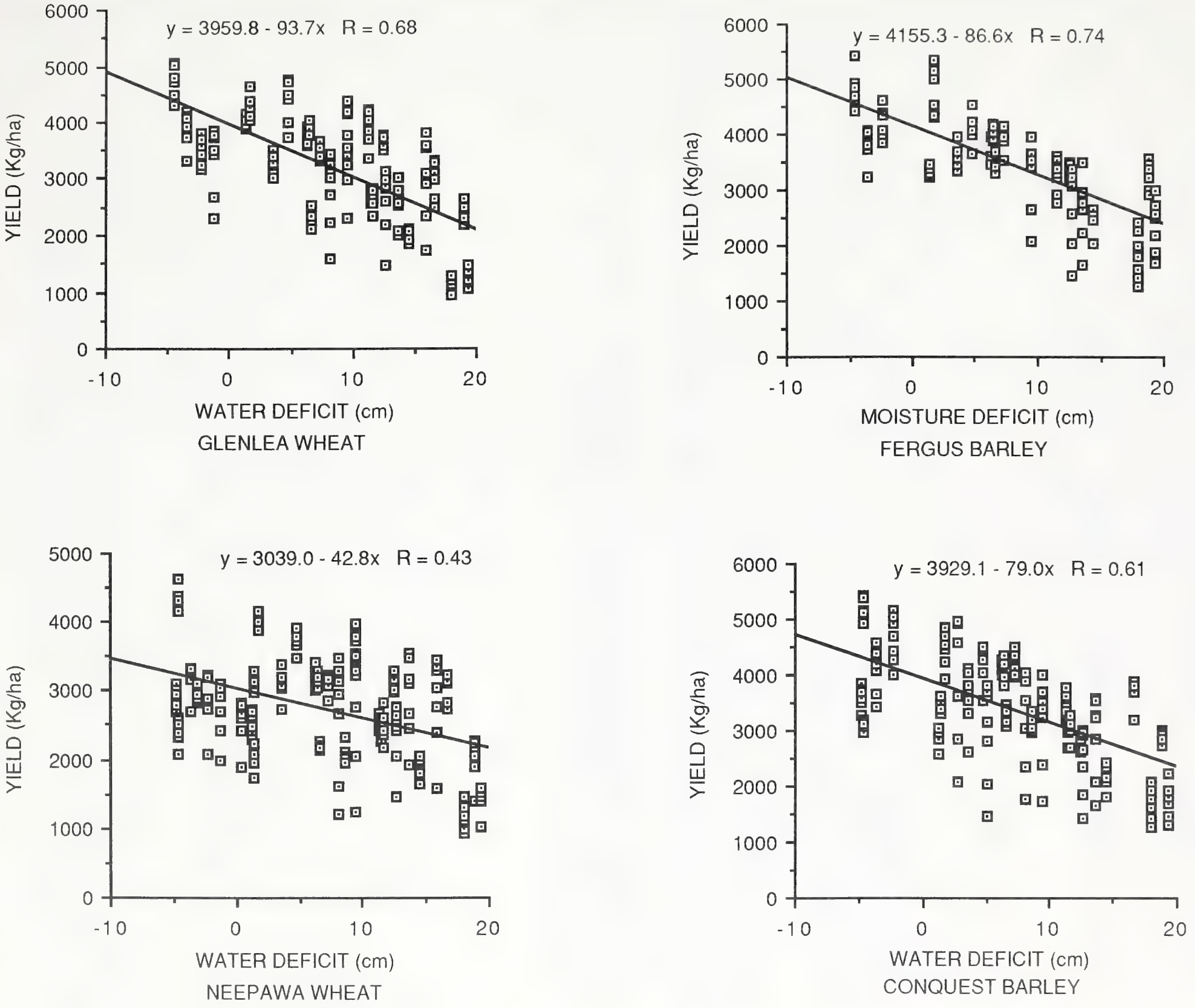


Figure 6. The effect of increasing moisture deficit on yield of four cereal crops in Southern Manitoba (1972-1975)

TABLE 6. REGRESSION COEFFICIENTS SHOWING THE EFFECT OF NITROGEN SUPPLY AND MOISTURE DEFICIT ON YIELD OF WHEAT AND BARLEY IN SOUTHERN MANITOBA (1972-1975)

CROP	VARIETY	INTERCEPT*	NITROGEN SUPPLY	MOISTURE DEFICIT	R	S.E.
Wheat	Neepawa	1882	7.47	- - -	0.53**	679
		3039	- - -	-42.8	0.43**	677
		1751	6.92	-33.6	0.63**	572
	Glenlea	2043	10.12	- - -	0.58**	751
		3959	- - -	-93.7	0.68**	727
		2833	8.13	-71.6	0.76**	593
Barley	Fergus	2576	9.09	- - -	0.55**	718
		4155	- - -	-86.6	0.74**	776
		3056	7.89	-43.5	0.76**	662
	Conquest	2336	9.17	- - -	0.52**	791
		3929	- - -	-79.0	0.61**	780
		2543	8.62	-26.2	0.66**	768

* kg/ha

Moisture Deficit: Change in soil moisture (Seeding to harvest) + Growing season precipitation - potential evapotranspiration

Nitrogen Supply: Soil nitrogen + fertilizer nitrogen (kg/ha)

** Significant at P = 0.01

RANGELAND, THE DROUGHT-ADAPTED CROPPING SYSTEM

Barry W. Adams[1]

ABSTRACT

Rangeland is often considered wasteland, whose only productive use is livestock grazing. Rangeland ecosystems have evolved in the drought prone prairie environment. Well managed rangeland is an asset in drought years as healthy, deep-rooted native grasses produce most of their yield in spring prior to peak summer temperatures and periods of greatest leaf moisture loss.

Overgrazing produces a form of man induced drought, the effects of which are most keenly felt during periods of drought. Canadian range scientists, managers and producers have evolved effective range/forage management systems that make healthy rangeland a drought adapted cropping system.

Current management systems will be reviewed along with research needs relating to stocking rates, grazing systems, range recovery, equipment, weed control and forage crops. Extension and demonstration needs will also be discussed.

INTRODUCTION

For many, rangeland is considered a type of land too sandy, arid, rough, frost prone or chemically adverse to support cultivated agriculture. Even today, Statistics Canada classifies rangeland as other unimproved land. In the context of our theme, moisture management in crop production, I would like you to consider well managed rangeland and pasture as a special drought adapted cropping system. In this presentation I will briefly explain why well managed rangeland is actually an asset during drought and the problems caused by overgrazing. I will then review a number of management factors that contribute to well managed range/forage resources and identify major research needs. Finally I will reflect on range/forage research and extension capabilities and trends which have a bearing on technology transfer to the producer.

In preparing this paper I have consulted a number of researchers, specialists and producers from across the western provinces (listed with references). Given the general nature of this topic I will be limiting my discussion to that of the most drought prone areas of Western Canada, namely the mixed grass prairie, fescue grassland and aspen parkland.

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Canada's Range and Forage Resources

Canadian range and forage resources are extensive and diverse, most of which are situated in Western Canada. There are 45 million acres of native grassland including mixed prairie, fescue grassland and parkland types. Of the tens of millions of acres of deciduous woodland that have potential for unimproved grazing only about 4 million acres are currently occupied. Seeded pasture and haylands occupy 6.2 and 7.4 million acres respectively. This native and tame forage base supports 6.7 million cattle.

In Canada, we are fortunate to have escaped the high degree of rangeland plowing or "sodbusting" that has occurred in the north central and western United States. This trend appears to have been motivated by a variety of grain subsidies and for speculative gains. Although certain suitable lands were converted to crop land, the major concern was over those rangeland soils that could not sustain cultivation. Though the trend appears to have been halted the higher proportion of rangeland to cropland north of the 49th parallel is quite apparent on satellite imagery.

RANGELAND THE DROUGHT ADAPTED CROPPING SYSTEM

Rangeland can be considered a drought adapted cropping system. Well managed native grasslands tend to have a high proportion of deep-rooted grass species. These range grasses are capable of making use of available moisture, well after the shallow rooted annuals are experiencing drought. Dryland farming requires spring moisture reserves plus growing season precipitation to successfully produce a crop. Rangeland will produce a portion of its normal production in spite of a lack of growing season precipitation.

The reliability of well managed rangeland to produce during drought conditions is evident from yield values on 16 native range sites in Southern Alberta from the period of the recent drought. In both 1984 and 1985, 10 out of 16, or 60%, of the test sites produced within 20% of normal yields. Only 6 out of 16, or 40%, of the test sites had significantly below normal production levels (50% of normal).

Why then was forage in such short supply during this period? The most aggravated forage shortages occurred where managers were attempting to use native or tame forage as an annual crop. We can obtain a more comprehensive answer to this question by examining a number of principals that range research has taught us about grazing effects. In many respects, range and pasture management relies more upon the understanding of ecological principals rather than agronomic ones. I believe this is exemplified in the following description:

> Persistent heavy grazing results in a form of man-induced drought. In the mixed prairie such heavy grazing tends to reduce the density of taller plants and reduces the amount of litter protecting the soil. A variety of factors are modified in the plant-soil environment, most of which are moisture related.

- The main effect is a reduction in soil moisture supply by reducing soil organic matter and vegetative protection of soil surface.
- Infiltration rates for precipitation are reduced and more moisture evaporates or runs off.
- Increased soil temperatures during summer further add to evaporative losses.

Because the plant environment is changed:

- plant vigour is reduced and this is reflected in reduced plant height and density
- eventually changes in floristic composition occur because heavy grazing has made the plant-soil environment even drier than normal
- deep-rooted desirables are replaced by weedier, more shallow rooted species that produce less forage of poorer quality.

The primary objective of a grazing system should be to promote plant succession.[1] In the mixed prairie we should adopt measures that will ensure adequate litter for moisture conservation and foster conditions that favour the taller, deep-rooted species that can obtain maximum available soil moisture. We also want to minimize the grazing of these native species during the most active period of early season growth.

In the fescue grasslands litter conservation is not as critical, but rather the timing and intensity of grazing. Optimum native forage production is obtained by grazing after the active growth phase.

RANGE RESEARCH NEEDS

Range research and rancher experience have evolved a program of management and rehabilitation that have stood the test of time, the basics of which include:

- to distribute livestock evenly over the range
- to balance livestock numbers with available forage
- to graze range at the right time; consider the management needs of key plant species
- to provide alternate spring pasture within a grazing system so that grazing of native grassland can be delayed until later in the season.

In the following discussion the components of management that contribute to well managed range/forage resources are discussed with respect to the mixed prairie, fescue grassland and aspen parkland.

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[1] Plant Succession - The process of vegetational development whereby an area becomes successively occupied by different plant communities of higher ecological order.

Stocking Rates

Stocking rate guidelines have been developed for much of the western provinces to help balance livestock numbers with long term available forage levels. For the most part guidelines have been well studied and documented. Some local refinements are required though, particularly in the foothills and aspen parkland. The updating of existing recommendations is a normal ongoing process. The key point is that recurring drought is a feature of the prairie region. Stocking rate recommendations should be designed to include drought years and the accompanying reduction in forage levels as a normal occurrence. Drought is to be managed for as part of the long term picture.

Grazing Systems

Grazing systems are employed to determine where and when livestock are permitted to utilize an area. Grazing systems are designed to consider the needs of rangeland and livestock production.

Continuous grazing is most commonly practiced on the prairies. This involves one field grazed season long and works reasonably well as long as animals are well distributed and numbers do not exceed available forage. A negative aspect is that livestock may "patch" graze the same areas of range year after year with some plants receiving repeated heavy grazing while others go ungrazed.

Another system, deferred-rotational grazing allows for early season use of one field out of two or three fields in a given year. Early season use is assigned to other fields in alternate years. On the fields where grazing is delayed, key forage species can gain vigour, set seed and permit new seedlings to establish. This system is useful for rehabilitating overgrazed range.

Complementary grazing systems are most commonly recommended. Seeded pastures are established using adapted cultivars. Species seeded for spring grazing, such as crested wheatgrass, permit deferral on native range every year rather than alternate years. The full growth potential of the native range can thereby be promoted. Thus with good condition native range, grazing may be extended into autumn and even through winter. Where the quality of native forage is not adequate grazing may be extended with seeded forages such as Russian wild rye and Altai wild rye.

Rest-rotational systems involve the complete resting of a particular field for the entire grazing season. Rest-rotations are not commonly practiced but may be employed on range with a very long history of overgrazing or where management objectives other than livestock grazing are required.

In practice a rancher may combine several systems such as complementary and deferred rotations. A substantial body of research findings are available on these basic systems from both Canadian and U.S. sources.

These types of grazing systems tend to be practiced on most medium and large scale holdings where a viable scale and level of flexibility are retained. Ranches or community pastures in this category tend to be in good to excellent condition. However the structure of the prairie livestock industry is changing. Our major range management problems occur on the smaller scale fragmented holdings. One third of our beef cattle are on farms smaller than 640 acres and half of the calves come from herds of 26 cows or less. Additional research is required to adapt and demonstrate effective grazing systems for small ranches and mixed farming operations.

Holistic Resource Management

In recent years considerable interest has been expressed in what has been variously described as the Savory Grazing Method and Holistic ranch or resource management (HRM). In general terms the philosophy encourages ranchers and resource managers to "Apply a management model which incorporates a holistic view of land, people and dollars". Allan Savory, a management consultant from Albuquerque, Mew Mexico, is recognized as the key promoter of this philosophy, although Stan Parsons also offers training to producers and land managers. As it has been practiced, HRM has been regarded most commonly as a high intensity, short duration grazing system. Although HRM encompasses many facets of management, only the recommended grazing management practices will be addressed here. The key points are that:

a) special management is required to evenly distribute livestock, this is usually done with fencing but could be done with herding as well.
b) high stocking densities are required to impose animal impact in the form of hoof action.

These measures are intended to increase soil litter and organic matter levels by distributing manure and incorporating duff into the soil. Soil water status and seedling establishment are thereby improved. The goal is improved productivity by increasing the health of the grassland.

The general consensus among researchers at this time is that we simply don't know enough about the grazing management prescribed by HRM to judge its value for our rangelands. Research is required to examine the effects of:

a) the animal impact in the form of hoof action,
b) the timing of grazing,
c) and intensity of grazing,

which are advocated to enhance water and nutrient cycling and improve species composition and productivity. Soil organic matter and plant-soil relations should be stressed. The importance of litter, particularly in the mixed prairie, was stressed earlier. At present, there is concern about litter conservation under such a grazing regime.

Range Recovery

Managers lacking flexibility and feed reserves and who may be in an overgrazing situation prior to drought, will face destocking as an inevitable measure. The first step to range recovery is to recognize that range condition has deteriorated or the current status of soils and vegetation have declined from what is possible with good management. A sufficient reduction in utilization of the forage will allow vegetation to recover.

We can't predict drought, until it occurs. The best tool is to consistently defer grazing of drought prone rangelands during the critical spring growing season. Once again provision of spring pasture in the form of annual or perennial forages will permit rest and deferment of overgrazed native range. Some grazing may yet be obtained from the rested rangeland by grazing it in the dormant period. Recovery may take 5 to 10 years depending on the degree of overuse. Longer recovery periods will be necessary where the remnant of desirable plants and seed reserves have been exhausted. Long term overuse carries a heavy cost for rehabilitation in terms of both improvement costs and reduced forage yields. A full complement of adapted cultivars are required to make this approach work.

Once the reason for the problem is recognized, regrassing may be the most practical option on poor condition sites. One promising technique involves the killing of the old sod with Roundup (Glyphosate) followed by sod seeding of native or exotic forages with a specially designed range drill. More work is required in practical demonstrations of this technique.

Weed Control

For rangeland and pasture, the management of plant succession remains the key to controlling most undesirable plant species. Nonetheless some special research priorities exist:

- Weed control techniques in new forage stands.
- Effective biological controls for leafy spurge, diffuse and spotted knapweed are required.
- Further testing of new herbicides and refinement of brush control procedures for foothill and parkland range is necessary.

Fertilization

Heavy nitrogen applications on rangeland have been found to sustain fivefold yield increases over a 10 year period. Given the economics of the day though, this is not commonly practiced. Less than 25% of prairie producers use fertilizer on range or pasture. Fertilization does show potential for improving livestock distribution into poorly used areas by improving forage palatability.

Equipment Needs

Many specialized types of range improvement equipment were developed on the prairies during the most active phases of range development work carried out by the P.F.R.A. Apart from the land clearing and breaking equipment that has subsequently evolved for use in the boreal forest, there has been little real development and innovation of rangeland equipment since the 1960's.

The P.F.R.A. range drill, developed from the Oregon model was very useful for seeding rough land. Many units are still in use in Saskatchewan. Few if any are available in Alberta and the drill requires further refinements.

Additional research work is required to develop tillage and seeding equipment for marginal agricultural soils particularly for stony parkland soils.

Forage Crops

Given the preceding discussion, seeded forages are integral to effective range management on the prairies. We can't expect maximum yields from native range without deferment of grazing during the vulnerable spring period. Aside from their role in improving native range, forage crops help "extend the grazing season, supply grazing needs for special purposes, and may increase the grazing capacity by three to sixfold". Forage crops should be versatile so that, depending on changing objectives and climatic conditions, they can be grazed, hayed, ensiled or harvested as a seed crop.

Forage crops have particular value in crop rotations to abate and reverse soil degradation on better agricultural lands and to rehabilitate depleted marginal lands.

Further research should concentrate on cultivars for spring and fall pasture in the foothills and parkland. Orchardgrass is an excellent candidate for spring pasture but requires further improvement of winter hardiness.

Other promising species such as Walsh western wheatgrass, Elbee northern wheatgrass, Regar meadow brome and Altai wild rye require further evaluation and promotion.

Efforts should continue in the developing and promoting the use of annual forages like oats, fall rye, wheat, barley and ryegrasses for supplemental grazing.

Innovative Range Improvement Technology

Poor economic returns are most commonly blamed for the generally low acceptance and implementation of range improvements and grazing management systems. Many researchers maintain that "we must increase the productivity of rangeland and pasture to a level that is economically competitive with grain crops." To this end much more intensive management along agronomic or farming lines would be required to meet this goal.

But what of the more innovative forms of range improvement. Range research has barely scratched the surface in terms of procedures integrating such tools as fire and livestock grazing to maintain certain levels of plant succession and production. Although the management requirements would be higher, such treatments would have a lower opportunity cost than agronomic practices and be less environmentally disruptive. In one rancher's words, "Ranching, contrary to many forms of agriculture, does not need to impose drastic changes on the environment. We don't have to remake the world to meet our goals of grass production, sustained and perhaps even improved."

An example relevant to our theme would be the improvement of willow forest in the foothills of western Alberta combining prescribed burning and controlled grazing (contained with portable electric fence). Instead of the conventional approach of bulldozing willow forest thus reducing the cover of snow trapping vegetation, why not maintain it in a more grazeable growth form, with fire and grazing, that serves to trap snow and enhance soil moisture supplies.

APPLIED RESEARCH, EXTENSION AND DEMONSTRATION NEEDS

One of the ironies of our time is that space age technology has given us a new capability to identify overgrazed range with satellite imagery. Yet we have not made the same quantum leap in taking action and correcting the problem.

Indeed, many workers in this area feel that a progressive decline is underway and that the recent drought has intensified this trend. Conservative estimates indicate that 40 to 50% of our native range on the prairies is in fair to poor condition. This means that in average years these lands produce less than half of what they are capable of and are more prone to drought than better condition grassland. What needs to be done to improve the management of range resources? Range and forage management must be given a higher priority.

After two or three years of drought, there is renewed interest in grassland management. For the producer and society to benefit from range research though, the chain from basic and applied research, through extension and demonstration and finally technology transfer to the producer, must be complete. Unfortunately our basic capability to do this appears to be declining.

Agriculture Canada has served as the foundation and cornerstone of range research since 1927. In spite of this agency's past good record and the need for additional work, future prospects for range research appear dismal. The number of range management or range ecology-trained scientists conducting research full time in western Canada has progressively declined from a high of 10, 20 years ago, to two at the present time. In the foreseeable future there may only be one remaining. Pressure must be exerted to encourage the federal government to retain a viable range research capability.

Research funds are difficult to obtain for range work. University researchers already short staffed, find themselves trying to compete for funding against biotechnology programs. This is combined with falling enrollments in range/grazing options. Special funding sources are required to ensure adequate ongoing support for teaching and research.

The priority for provincial agencies should be in the area of applied research, extension and demonstration initiatives. The substantial body of existing information must be more effectively applied. It's not enough to simply provide information. Effective extension programs must place an emphasis on demonstration projects as well. Like people in general, producers are both technical and intuitive in their assessment of new technology. For many a mountain of technical bulletins can't compare to seeing a new grazing system in practice.

Once again though there are problems in meeting this goal. The present reality is that provincial range management specialists are limited in number in the three prairie provinces. In fact, B.C. has as many specialized staff working in applied range research and extension as the three prairie provinces combined (B.C. rangelands support .35 million cattle while the prairies 6.4

million). In recent years, demonstration funds have been made available in Alberta and Saskatchewan but there are insufficient range specialists to promote, design and manage such projects.

For the more generalized group of extension workers such as Agricultural Reps., District Agriculturalists and Resource Agrologists the current economic realities and priorities in government means that these staff are involved more in program administration than in working with the producer and solving grazing management problems. The present situation then is that manpower and resources for range extension are limited and are apt to remain so for the foreseeable future.

The consequences of ignoring the problems of our western rangelands will have immense ecological, economic and social ramifications. Surely the magnitude of the problems transcends all boundaries between government agencies, educators and producers alike. A valuable first step may be improved communication between the provinces with those agencies and groups with an interest in range/forage resources. For provincial agencies, dialogue on successful management systems, promising new research and technology transfer would be extremely fruitful and reduce a certain amount of duplication of effort. This form of dialogue is already well established in other facets of Agriculture and Forestry.

One possible mechanism for dialogue would be an interprovincial rangelands committee involving key people from Provincial agriculture, lands and forestry jurisdictions, Agriculture Canada, the universities, producer groups and the Society for Range Management. Specific tasks that such a committee should address are:

a) Prepare a formal, detailed inventory of basic and applied research, extension and demonstration needs in range/forage management.
b) Communicate effective models and approaches to technology transfer in range/forage management.
c) Explore, design and report mechanisms to encourage good grassland management such as a system of incentives in our taxation and grazing fee schedules to encourage good range management practices.

SUMMARY

Prairie cropping systems have relied upon soil organic matter reserves built up over the centuries by native grassland. The depletion of soil organic matter levels under traditional farming practices is now well documented. How will we manage the remaining third of prairie soils that are rangeland?

Rangeland plant communities are adapted to prairie soils and climate; to the inherent soil chemistry, fertility and moisture supply. Well managed native grassland is an asset in drought years as deep-rooted native grasses make use of available moisture, well after the shallow rooted annuals are experiencing drought.

Although much new research is required, many of the answers to range/forage management problems are already available. What is the extent of our collective resolve to promote the best possible management of our range/forage resources? Surely well managed rangeland has a place in a long term livestock production strategy and would ensure a comparative advantage to Canadian producers.

Many other resource interests such as wildlife, watershed and recreation, share a vital interst in these lands as well and are depending upon range managers to do an effective job.

Drought can be a devastating phenomena for the producer and the environment, but it can be also regarded as an opportunity for change. Will we be prepared to adopt sustainable range/forage production systems prior to next drought or will the lessons of the last one have to be relearned.

Major Research Needs

- Monitoring of native range production and refinement of stock rate recommendations should be ongoing. This is particularly important for the foothills and aspen parkland.
- Additional research is required to adapt and demonstrate effective grazing systems for small ranches and mixed farming operations.
- Research is required to examine the effects of various grazing practices prescribed by advocates of Holistic ranch or resource management on Canadian range soils and vegetation types. Researchers, extension workers and land managers are in no position to recommend such an approach until research work has been carried out.
- Range weed research should be encouraged with particular emphasis on control of weeds in new forage stands, knapweed and brush species.
- The ongoing development of perennial and annual forage crops that permit complementary and supplementary grazing should be encouraged. Priority should be given to cultivars for spring grazing in the foothills and aspen parkland regions.
- Innovative research is required to evaluate and integrate low-cost range improvement techniques, such as fire and livestock grazing, particularly for brush management.

RECOMMENDATIONS

1. That a formal dialogue be established between the western provinces to communicate research, extension and demonstration activities and needs in range/forage management.
2. That provincial agencies give higher priority to applied research, extension and demonstration initiatives to better apply existing knowledge in range/forage management.
3. That representation be made to encourage Agriculture Canada to maintain a viable range/forage research capability in Western Canada.

CONTRIBUTORS

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PLENARY SESSION III

ALTERNATE SOLUTIONS AND FUTURE DIRECTION

CHAIRMAN, D. DOYLE, ASSISTANT DEPUTY MINISTER,
WATER RESOURCES, MANITOBA NATURAL RESOURCES

AN EVALUATION OF SEASONAL PRECIPITATION FORECASTING: A LOOK AT THE STATISTICS AND FORECAST TOOLS

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For agricultural purposes, forecasts of precipitation are generally of greater value than temperature. Unfortunately, experience shows that precipitation forecasts are generally of lower skill. This paper addresses the problems inherent with precipitation forecasts. Seasonal skill scores of precipitation and temperature forecasts are compared. After addressing the temporal and spatial skill scores of precipitation, difficulties in making precipitation forecasts are then discussed.

Current methods of extended-range-forecasting are highly dependent upon the persistence of large-scale atmospheric anomalies. Since regional temperatures are more spatially coherent and better related to time averaged atmospheric circulation, temperature forecasts based on expected circulation regimes should be more successful than precipitation forecasts. Unlike temperature, precipitation is poorly correlated in both time and space; thus, slight shifts in atmospheric circulation are more likely to alter precipitation patterns than they are to alter temperature patterns.

While skill scores of seasonal precipitation forecasts are generally low, they do remain higher than that expected by chance. Analysis of regional skill scores indicates that precipitation forecasts in certain parts of North America are relatively successful — while other regions show skill scores with little improvement over chance. For regions with significant skill score, two-season forecasts (4 to 6 months in advance) appear to have accuracies similar to the one-season forecasts (1 to 3 months). Recent research indicates that precipitation frequency (number of days with precipitation $\geq$0.10") may be a variable better related to the time-averaged precipitation than is the commonly used value - precipitation totals. However, there is no indication from the user community that precipitation frequency is better related to agricultural decision-making processes.

To date, Canada has relied upon seasonal forecasts from the United States. However, during the past year the Canadian government has begun to issue experimental monthly and seasonal forecasts. Potential users of the Canadian forecast materials should work closely with the government to outline the type of forecast information that is useful to them. For example, is precipitation frequency more important than precipitation totals, or are seasonal class limits (expected departures) more important than placing probabilities of success on a forecast?

AN EVALUATION OF SEASONAL PRECIPITATION FORECASTING: A LOOK AT THE STATISTICS AND FORECAST TOOLS

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1. INTRODUCTION

A recent survey of groups receiving long-range weather forecasts indicates that accuracy and lead time were of utmost importance to most subscribers (Easterling, 1986). The survey found that lead time was of particular importance to both the agricultural community as well as suppliers of energy. In this paper we assess the accuracy of seasonal long-range forecasts (3 months) and two-season forecasts (4-6 months in advance). The latter forecasts are considered experimental and have not been available to the public. However, two-season forecasts could be of considerable value to the agricultural community where long lead times of weather forecasts are critical to decision-making processes.

While seasonal forecast products are only available for the conterminous United States, it will be shown that forecast accuracy is slightly better along the western Canadian border and in the vicinity of the Great Lakes. This holds promise for expanding the areal coverage of the seasonal forecasts.

Over the past eight years, four independent groups have routinely produced forecasts of seasonal temperature and precipitation for the conterminous United States. The accuracy of these forecasts has been addressed in a study by Preisendorfer and Mobley (1984). They found in general that " . . . all forecasters found it more difficult to forecast precipitation than temperature." (Monthly forecasts are already available for Canada.

Difficulties in predicting both temperature and precipitation are addressed in this paper. Not too surprisingly, precipitation forecasts are found to have a poor track record compared to temperature forecasts. This is strongly related to the spotty nature of precipitation events — in both time and space. In the first section of the paper properties of seasonal precipitation are examined as they relate to the difficulties inherent with making three-month precipitation forecasts. Since seasonal forecasts must capture events during a three-month period, part of this study will also focus on the persistence of precipitation on a month-to-month basis.

The paper will report on the seasonal forecast skill scores and techniques of: Don Gilman and Colleagues of the National Weather Services Climate Analysis Center, Washington, D.C.; Dr. Jerome Namias, Scripps Institution of Oceanography, La Jolla, California; the analog method of Drs. Tim Barnett, of Scripps, and Rudy Preisendorfer, of NOAA PMEL, Seattle, Washington; and Dr. Art Douglas, Creighton University, Omaha, Nebraska.

2. PRECIPITATION: THE STATISTICAL PROPERTIES.

Unlike temperature, precipitation tends to be discontinuous in time and space. Thus, as a discrete element, precipitation need not be strongly related to time-averaged pressure or circulation (jet stream patterns). For this reason alone, one should immediately expect less relationship between seasonal weather patterns and precipitation. For example, a region may be dominated by a persistent high pressure with warm, dry weather through much of a 90-day period. However, a few breaks in this dry regime could allow a few short periods of intense heavy precipitation to occur, with cooler-than-normal temperatures. The end result might be a near normal precipitation season despite intraseason drought with above normal temperatures and a pressure chart which appears "dry". This misleading situation is compounded by the fact that most extended range forecasters attempt to predict seasonal precipitation from expected atmospheric pressure patterns — hoping that the pressure pattern will remain fairly persistent. Not surprisingly, a good pressure forecast for a 90-day period may not be associated with a good forecast of precipitation (as in the example above)..

The spatial aspect of precipitation is more complex than that of temperature, and this makes the former variable harder to predict. This can be seen when the two variables are submitted to eigenvector analysis (a statistical procedure which points out preferred mean spatial patterns). Compared to temperature, almost twice as many precipitation eigenvector patterns are required to explain the variance in precipitation (Table 1). This is a direct result of the tendency for precipitation anomalies to occur on smaller space scales that those of temperature — at times almost to the point that seasonal precipitation patterns appear to be almost random (Preisendorfer and Mobley, 1984).

In Table 1, it can be seen that typically 60% to 80% of the variance in monthly temperature can be captured in the first three eigenvectors (spatial patterns) but only 35% to 45% of the variance in monthly precipitation is captured by the first three modes. During the summer, the difference in space scales between temperature and precipitation are accentuated due to the spotty convective nature of the rainfall. This contrast is illustrated in Figure 1 which depicts the first two eigenvectors of July temperature and precipitation.

These statistics suggest that a broad brush approach to temperature forecasting may yield moderate success, assuming a forecaster has a "feel" for the upcoming seasonal circulation. However, the finer scale of precipitation anomalies would suggest that spatially more accurate forecasts of jet stream patterns would be required before precipitation forecasts are improved. At best, this type of fine tuning is not available beyond three or five days. Even if such finely tuned predictions of seasonal circulation were available, one would still need to keep in mind that any potential break in a persistent circulation regime could strongly alter the overall seasonal precipitation.

3. VERIFICATION RESULTS: PRECIPITATION vs TEMPERATURE

The National Weather Service has calculated skill scores for approximately twelve years of seasonal temperature and precipitation outlooks (Table 2). These verifications are based on more than 40 independent forecasts and the skill scores are based on records from 100 stations in the United States. The class system used is a 30-40-30 system in which the above normal (heavy) and the below normal (light) classes are each expected to occur 30% of the time during a given base period (typically 30 years). The normal class is larger and these values are expected to be observed 40% of the time. The results are expressed as the potential for a given forecast to be correct based on the verification results, but it should be noted that the normal class is artificially set at 40% (no skill assumed when making a forecast of "normal"). In examining these probability tables, the highest skill scores are associated with temperatures. Above normal temperatures are predicted 38.5% of the time; in other words, 8.5% greater than expected by chance. On the average, the skill scores for predicting precipitation extremes are approximately 4% below those found with temperature and only 3% better than that expected by chance.

Forecasts from the four prediction groups cited in the introduction have also been evaluated using an equal class (tercile) system. In a given base period, one-third of the data should fall in the upper class (above, or heavy), one-third in the middle class (normal), and one-third in the bottom class (below normal), or light). Standard Skill scores for the four groups have been computed using the following equation:

$$\text{Standard Skill} = \frac{C - 33}{99 - 33}$$

Where C is the number of correct forecast points out of 99.

In this system, by chance alone one would expect 33 points correctly forecast. Consequently, the standard skill score is only positive when more than 33 points out of the 99 are correctly forecast (see Preisendorfer and Mobley, 1984, for further details). These standard skill scores are presented in Table 3. Surprisingly, the precipitation forecasts of the National Weather Service and Namias are better than their temperature forecasts. One might conclude, therefore, that the tercile system is somewhat more favorable for verifying precipitation compared to the 30-40-30 class system which appears to be more favorable for verifying temperature. Additional research should be conducted to show why this discrepancy occurs between the two methods of verification.

The regions of significant forecast skill (90% level) are presented in Figures 2 and 3, which show the contrast in geographical skills of temperature and precipitation. Clearly, temperature forecasts are skillful over a broader geographic range on an annual basis. The accuracies of seasonal forecasts for the four standard seasons are given in Figures 4-7. Readers interested in detailed evaluations of the seasonal skill scores are referred to the work of Preisendorfer and Mobley (1984).

4. PREDICTION OF SEASONAL PRECIPITATION

This section focuses on the various tools used to predict seasonal precipitation. In reviewing forecast methods, it must be stressed that most groups (except the analog method) have reshaped their forecast tools over the past few years. As such, the skill scores used in the following discussions are subject to changes in methodology and some slight improvement in forecast skills may be occurring.

4.1 Persistence of Precipitation

One of the earliest tools used in long-range forecasting was the month-to-month and season-to-season persistence of given meteorological variables (Namias, 1964). In some cases, persistence of temperature can be attributed to anomalous boundary conditions (snow cover, soil moisture, and nearby sea surface temperature anomalies, see Namias, 1978). While anomalous boundary conditions may affect temperature, researchers have found it difficult to link the effect of anomalous boundary conditions to anomalous precipitation regimes. On a concurrent basis, however, temperature and precipitation are well related especially during the summer in the Central Plains (Figure 8, taken from Namias, 1978). For much of the year, however, precipitation shows only a weak relationship with temperature. In addition, contingency tables or correlation maps depicting season-to-season persistence of precipitation anomalies are generally of little use to the long-range forecaster.

If persistence of precipitation is lacking on an interseasonal basis, how persistent is it within the season? This question, plus the recent practice of the NWS to produce overlapping seasonal forecasts, prompted Englehart and Douglas (1985) to examine the degree of intraseasonal persistence exhibited by precipitation frequency in each of the 12 overlapping seasons (i.e., persistence during the period December through February; January through March; etc.). The study uses the average rank-order correlation coefficient ($\bar{r}_S$) computed over all pairs of months within the defined season (See Englehart and Douglas, 1985b). The $\bar{r}_S$ values may be interpreted as a measure of overall agreement in monthly precipitation within a season. Of the possible 12 overlapping seasons, only 3 were found to exhibit significant intraseasonal persistence: January through March; March through May; and November through January (Figure 9).

These results indicate that precipitation frequency shows the greatest persistence during the November through January period. Almost 25 out of 60 climate divisions were found to exhibit significant persistence at the 90% level based on lag relationships during all possible combinations of months: from November to December; November to January; and December to January. The spatial distribution of $\bar{r}_S$ for this early winter period is given in Figure 10, with significant persistence occurring in well-defined storm track regions: the Pacific Northwest and from the Mississippi Valley into the Ohio Valley. Persistence is very poor during the transition season April through June (Figure 9). During this transition period, strong reversals in precipitation are likely and this lack of homogeneity makes it difficult to characterize seasonal precipitation regimes. Persistence of intraseasonal precipitation tends to be lowest during the fall (September through November). This helps to explain why Preisendorfer and Mobley (1984) found that precipitation forecasts for the fall had the lowest skill scores (Figure 11). In contrast, intraseasonal precipitation frequency shows some degree of persistence from November through May (Figure 9). This again supports the results of Preisendorfer and Mobley which showed winter and spring to be the seasons with the highest skill scores for precipitation (Figure 11). Since intraseasonal persistence is lacking from April through December (a total of seven overlapping seasons), one should expect considerable difficulty in making forecasts during this period, especially if persistence of precipitation regimes is used as a forecast tool.

4.2 Relationship between Temperature and Precipitation Skill Scores

A frequently asked question is: Are temperature skill scores well related to those of precipitation? In other words, is there really a significant relationship between the skill scores of temperature and precipitation? Based on 31 independent forecasts, a positive relationship was found between temperature and skill scores (Table 4). However, the correlations are relatively low for all forecast groups. This suggests that during the period 1977 to 1985 a successful temperature forecast was not necessarily associated with a successful precipitation forecast and vice versa. This stresses the need to directly forecast precipitation, rather than infer precipitation anomalies from expected temperature departures.

4.3 Seasonal Precipitation and 700mb Heights of the Preceding Season

Douglas and Englehart (1985) have developed a series of pattern correlation maps depicting the lag relationships between seasonal 700mb height anomalies and precipitation during the subsequent season. This technique is similar to the specification maps developed by Klein (1965). An example is shown in Figure 12, where spring 700mb heights are related to summer precipitation frequency in the Central Plains.

With this type of tool, a forecaster can assess the potential for anomalous precipitation in the upcoming season based upon the height patterns of the current season. If height anomalies are found in the same geographic locations as in the pattern correlation map, then a forecaster may suspect that significant precipitation anomalies are likely to occur in the upcoming season. Multiple linear regression equations derived from the analysis can be used to directly predict precipitation. This approach sidesteps the need to predict 700mb heights for the upcoming season. However, in many sections of the country, the pattern correlation maps are generally poor on a lag basis, and this stresses the need for accurate predictions of 700mb heights.

4.4 Low Frequency Predictors: El Niño and North Pacific Sea Surface Temperatures

The impact of changes in the Southern Oscillation Index (SOI) on world weather patterns is well documented, though considerable variation can occur from one El Niño to the next especially in the United States (Namias and Cayan, 1984). Douglas and Englehart

(1978) and Douglas and Englehart (1984) have found that cool season precipitation in the western and southern United States shows some relationship to variations in the Southern Oscillation. During El Niño years (low SOI), the southern United States (especially Florida and southern Arizona) tends to experience increased rainfall, while the Pacific Northwest tends to be somewhat drier than normal (Figure 13). However, variance in precipitation explained by changes in the Southern Oscillation is generally less than about 30% for these regions. This is not too surprising, since El Niño years and cold water years do not occur with great frequency.

North Pacific SST anomalies may offer even greater potential for seasonal forecasting. Much of the recent work of Namias (1975) has been devoted to demonstrating the relationships of North Pacific SST anomalies to the subsequent 700mb circulation over the North Pacific. In a more direct approach, Douglas (1982) has related North Pacific SST anomalies directly to eigenvectors of precipitation for the continental United States. The results tend to indicate that the best relationships between SSTs and precipitation occur from fall to early spring. An example of this type of analysis is given in Figure 14. Note that, at least in the case of the first two eigenvectors of precipitation, there is a tendency for the related SST anomalies to be in place during the antecedent season. The third eigenvector of precipitation shows very poor relationships with North Pacific SST anomalies.

4.5 Two-Season Forecasts

In making two-season forecasts, the tools outlined in the previous sections are applied to a period 4 to 6 months in advance. For example, a two-season summer forecast is issued on February 28, and winter conditions are used to specify the summer season 4 to 6 months from the forecast date. In Table 5, the forecast skill scores for two-season forecasts are compared to those of one-season forecasts. Two-season forecasts have skill similar to one-season forecasts. In general, two-season precipitation skill scores are quite low, but still positive, indicating they are only slightly better than chance. Two-season forecasts appear successful in reducing the number of 2-class errors (Table 6), and this fact alone may be useful to the agricultural community.

5. DECADAL FLUCTUATIONS IN SEASONAL PRECIPITATION

Decadal shifts in precipitation regimes have been discussed in a number of papers (e.g., Wahl and Lawson, 1970; Douglas, Cayan and Namias (1982). The work of Douglas, et al. (1982) addressed the change in precipitation in the United States for the period 1969-80 relative to the standard 30-year normals for 1941-70. Large scale changes in North Pacific SSTs and 700mb heights were found to be linked to the observed changes in continental precipitation. Surprisingly, in large portions of the country significantly different means in seasonal precipitation were present. In fact, for the 1969-80 period, the new means were significantly different enough so that the new normals fall into extreme tercile classes based upon the normals for 1941-70 (Figure 15).

While the recent work of Englehart and Douglas (1985b) tends to suggest a lack of coherency in precipitation within seasons, the results in Figure 15 point to large scale coherent shifts in seasonal precipitation regimes which were apparently persistent on a decadal basis. Thus, the long-range forecaster is confronted with the possibility that interannual persistence of seasonal anomalies may dominate on decadal time scales. But in any given year, intraseasonal persistence is still generally poor, making seasonal forecasting difficult.

The impact of the recent climate regime (post 1969) can be observed in the selection process of the analog model of Barnett and Preisendorfer (1978) which examines SST, thickness, and 700mb height anomalies. Since the winter of 1979-80 (a total of 22 seasonal forecasts) 73% of the analogs selected were from the very short period 1977-82. Thus, while the model employs data from 1947-present, in a vast majority of cases the best analog was selected from only a handful of recent years in which the precipitation anomalies exhibited strong resemblance to the decadal anomalies of Figure 15. Perhaps some of the success of the analog method is a result of the model's ability to identify persistent decadal regimes. Unfortunately, for the long-range forecaster it is difficult to determine if and when a new regime has commenced. Even if a new climate mode appears to have developed, shifts back to an original mode are still likely within the new regime. Additional research needs to be conducted to assess the potential value of using long-term trends in the preparation of seasonal precipitation forecasts. In addition, this type of research would need to stress the importance of developing reliable long-term means to be used in verifying seasonal precipitation frequency.

6. CONCLUSIONS AND RECOMMENDATIONS

Skill scores of seasonal precipitation outlooks are generally quite low, with significant skill (90% level) being found in less than half the country. Impediments to skillful prediction of seasonal precipitation are: (1) the discrete nature of precipitation; (2) smaller space scales of events which demand better resolution of predicted height fields; and (3) the general tendency for precipitation data sets to be non-normally distributed and consequently poorly suited to linear models.

Recent studies by Harnack and Lanzante (1985), Klein and Bloom (1985), and Englehart and Douglas (1985) indicate that precipitation frequency may be a variable better suited to seasonal forecasting than is the commonly used variable, precipitation totals. In addition, these three groups have found that areally averaged data sets are better related to time averaged circulation than are data sets employing single stations. Verification efforts in the future might be more satisfactory if regionalized time series were employed rather than single station data, which is the current practice in verification. While it is doubtful that any large improvement in forecast skills would be achieved by adopting precipitation frequency, the present state of the art might be helped by exploring this variable as a proxy to precipitation totals which admittedly are a more familiar statistic.

As pointed out by Preisendorfer and Mobley (1984), precipitation skill scores are especially poor in the summer. This is probably due in part to the spotty-convective nature of storms during the season, as well as the general tendency for persistence of intraseasonal precipitation to be poor from late spring to early fall. Any improvement in forecast skill during this period must rely on a better understanding of the physical processes associated with warm season precipitation. For this reason, exploratory work devoted to examining short period (weekly, bi-weekly, and monthly) precipitation fluctuations should continue (Richman and Lamb, 1985). Additionally, there should be some attempt to relate summertime precipitation patterns to other time averaged variables such as vorticity or upper tropospheric divergence (see Cayan and Roads, 1984).

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Table 1. Percentages of total variance described by the first three eigenvectors of temperature and precipitation totals. Analysis based on the period 1947-1978 (see Douglas 1981 for details).

MONTHLY % VARIANCE EXPLAINED
FIRST THREE EIGENVECTORS

VARIABLE	J	F	M	A	M	J	J	A	S	O	N	D
Temperature	80%	81	82	73	67	62	52	57	69	75	75	77
Precipitation	46	40	42	39	39	39	33	34	39	45	45	43

Table 2. Probabilities of obtaining a correct forecast based on approximately 10 years of NWS seasonal forecasts, data ending in 1984.

SEASONAL TEMPERATURE PROBABILITIES
FORECAST ANOMALY

		B	N	A
Observed	B	37.0%	30.8%	21.5%
	N	40.0	40.0	40.0
	A	23.0	29.3	38.5

SEASONAL PRECIPITATION PROBABILITIES
FORECAST ANOMALY

		L	M	H
Observed	L	33.6%	30.3%	27.4%
	M	40.0	40.0	40.0
	H	26.4	29.8	32.6

Table 3. Standard skill scores for the period Summer 1977 through winter 1984-85 (31 forecasts)

FORECAST	NWS	NAMIAS	ANALOG	DOUGLAS
Temperature	0.073	0.015	0.112	0.142
Precipitation	0.092	0.040	0.079	0.031

Table 4. Observed correlation (r) between the skill scores of seasonal temperature and precipitation (31 cases).

CORRELATION	NWS	NAMIAS	ANALOG	DOUGLAS
R	+0.25	+0.23	+0.34	+0.39

Table 5. Standard skill scores for 1-season and 2-season forecasts. Summer 1977 through winter 1984-85, 31 single season forecasts and 30 2-season forecasts.

1-SEASON		TEMPERATURE	PRECIPITATION
NWS	NWS	0.073	0.092
	NAMIAS	0.015	0.040
	ANALOG	0.112	0.079
	DOUGLAS	0.142	0.031
2-SEASON	DOUGLAS	0.076	0.023

$$SS = \frac{\text{No. Correct} - 33}{66 - 33}$$

Based on a 99 Point Grid

Table 6. Verification of 2-Season Forecasts, 4-6 Month lead time. Based on 30 Forecasts (Fall 1977-Winter 1984-85). Verification using equal class system.

Forecast	Number Correct	Errors 1-Class	Errors 2-Class
Temperature	38%	49%	12%
Precipitation	35%	49%	15%
Chance	33%	44%	22%

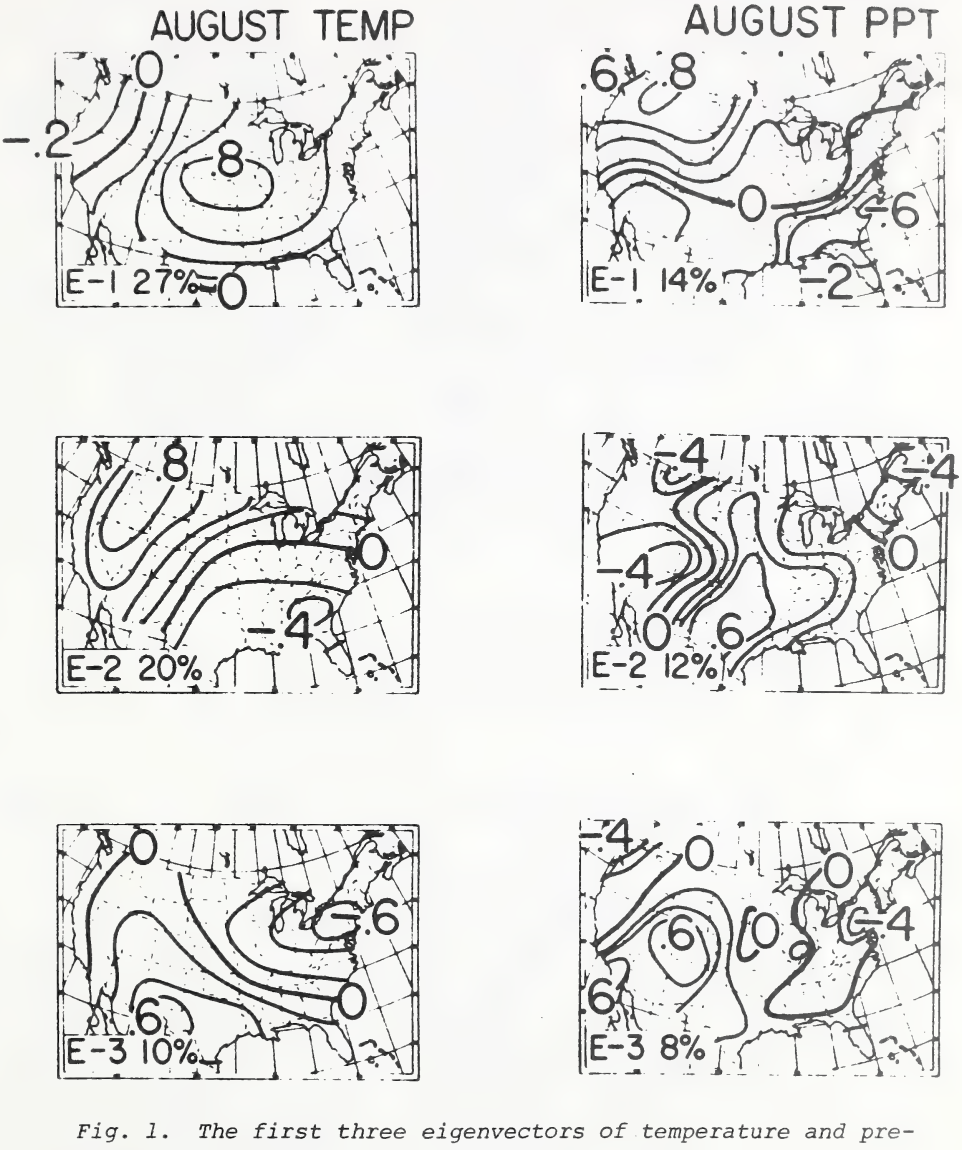

AUGUST TEMP
AUGUST PPT
0
-.2
.8
E-1 27%
0
.6
.8
0
.6
.2
E-1 14%
.8
0
.4
E-2 20%
.4
.4
.4
0
.4
0
.6
E-2 12%
0
.6
0
.6
E-3 10%
.4
0
0
.6
0
.4
.6
E-3 8%

Fig. 1. The first three eigenvectors of temperature and precipitation for August. The percent variance explained by each eigenvector is given in the lower left of each map. Period of analysis 1947-78.

U-PERCENTAGES FOR TEMPERATURE
SUM OF HUMAN FORECASTERS (24 FORECASTS MADE)
FALL (1974-1982)
U CRITICAL = 44 FOR THE 90 PERCENT CONFIDENCE LEVEL

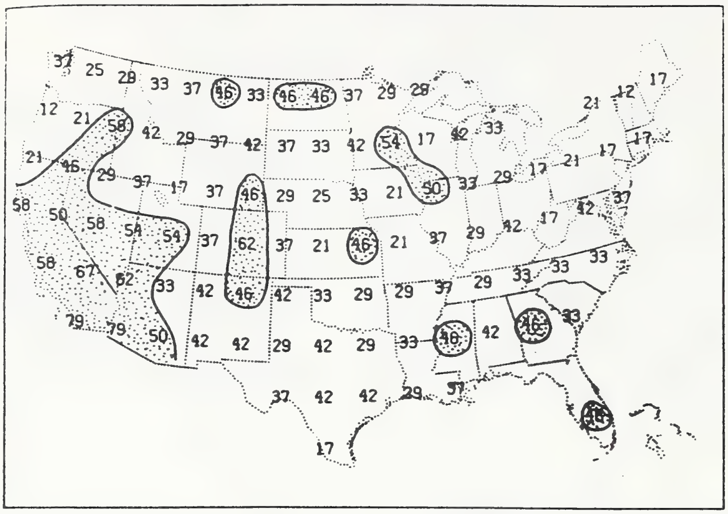

37 25 28 33 37 46 33 46 46 37 29 28 12 17
12 21 58 42 29 37 42 37 33 42 54 17 42 33 21
21 46 29 37 17 37 46 29 25 33 21 50 33 29 17 21 17 17
58 50 58 54 54 37 62 37 21 46 21 37 29 42 17 42 37
58 67 62 33 42 46 42 33 29 29 37 29 33 33 33
79 79 50 42 42 29 42 29 33 46 42 46 33
37 42 42 29 37 46
17

Fig. 2. Distribution of significant u scores (0-class errors) for all four forecast groups based on seasonal forecasts of temperature.

U-PERCENTAGES FOR PRECIPITATION
SUM OF HUMAN FORECASTERS (101 FORECASTS MADE)
ALL SEASONS COMBINED (1974-1982)
U CRITICAL = 39 FOR THE 90 PERCENT CONFIDENCE LEVEL

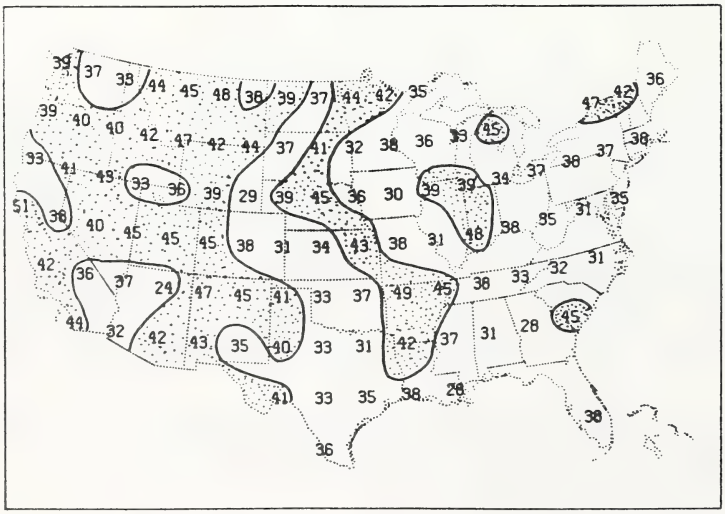
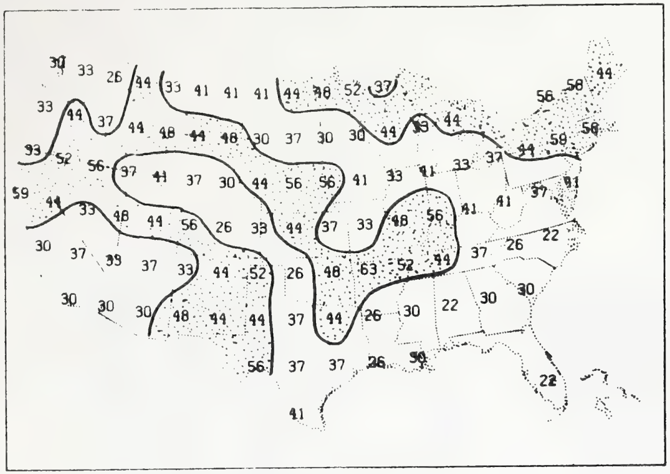
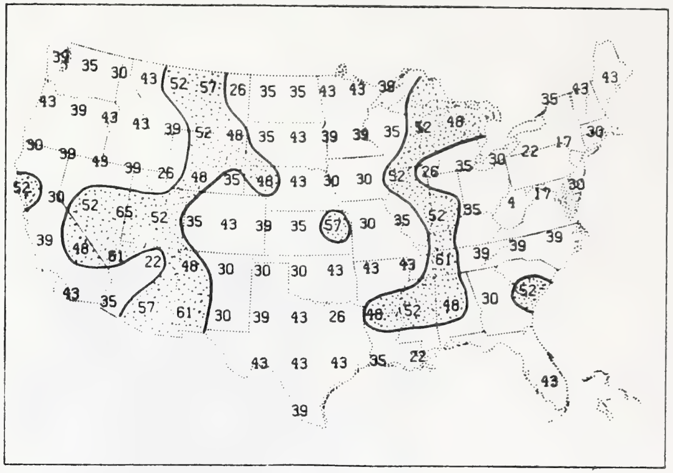

39 37 33 44 45 48 36 39 37 44 42 35 47 42 36
39 40 40 42 47 42 44 37 41 32 38 36 33 45 37 38 37 38
33 41 43 33 36 39 29 39 45 36 30 39 39 34
51 38 40 45 45 45 38 31 34 43 38 31 48 38 35 31 35
42 36 37 24 47 45 41 33 37 49 45 38 33 32 31
44 32 42 43 35 40 33 31 42 37 31 28 45
41 33 35 38 28 38
36

Fig. 3. Distribution of significant u scores (0-class errors) for all four forecast groups based on seasonal forecasts of precipitation. Note decrease in areal extent of forecast skill.

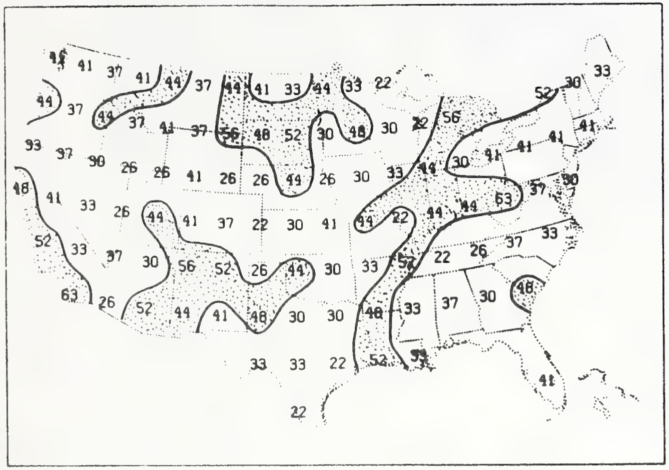
U-PERCENTAGES FØR PRECIPITATIØN
SUM ØF HUMAN FØRECASTERS (27 FØRECASTS MADE)
WINTER (1974-1982)
U CRITICAL = 43 FØR THE 90 PERCENT CØNFIDENCE LEVEL



SUM ØF HUMAN FØRECASTERS (23 FØRECASTS MADE)
SPRING (1974-1982)
U CRITICAL = 44 FØR THE 90 PERCENT CØNFIDENCE LEVEL



U-PERCENTAGES FØR PRECIPITATIØN
SUM ØF HUMAN FØRECASTERS (27 FØRECASTS MADE)
SUMMER (1974-1982)
U CRITICAL = 43 FØR THE 90 PERCENT CØNFIDENCE LEVEL



U-PERCENTAGES FØR PRECIPITATIØN
SUM ØF HUMAN FØRECASTERS (24 FØRECASTS MADE)
FALL (1974-1982)
U CRITICAL = 44 FØR THE 90 PERCENT CØNFIDENCE LEVEL

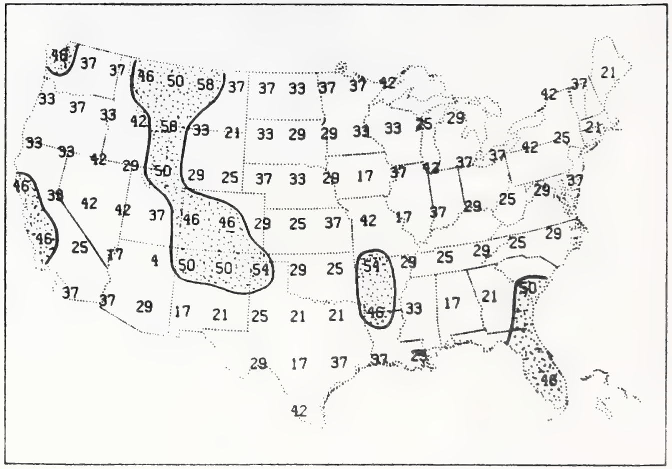


Fig. 4-7. Same as Fig. 3, except for the individual seasons.

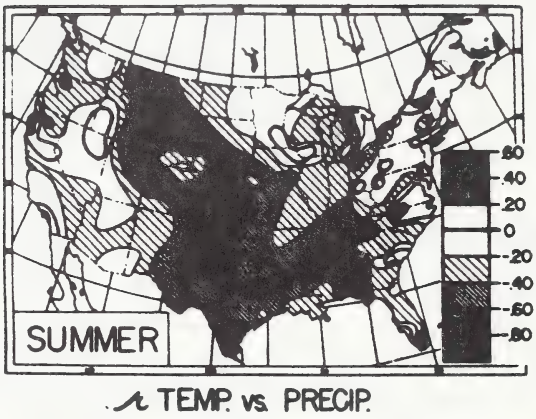

SUMMER
.60
.40
.20
0
-.20
-.40
-.60
-.80
r TEMP. vs. PRECIP.

Fig. 8. Contemporaneous seasonal correlations between temperature and precipitation in summer (based on data for 1947-72). Isopleths are drawn for each 0.20 beginning with ±0.20. Note high negative correlations over the Great Plains.

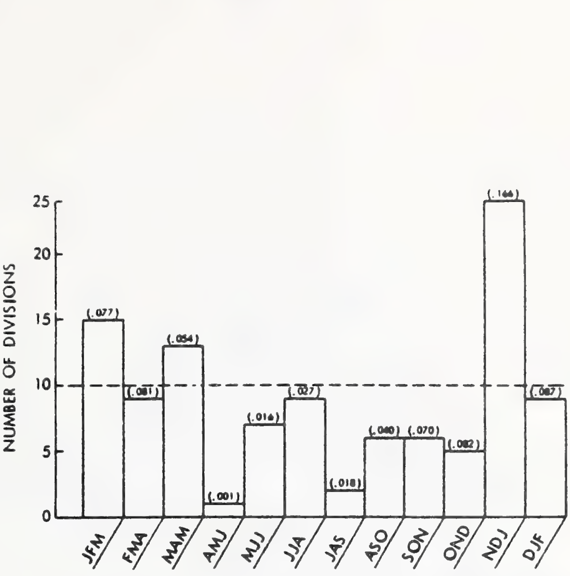


Fig. 6. Summary measures of $\bar{r}_s$. Histogram shows number of divisions with $\bar{r}_s$ values significant at the 90% level. Numbers in parenthesis refer to the median $\bar{r}_s$ value taken over the 60-division grid. Dashed line represents 90% field significance under the assumption of independence.

Fig. 9. Summary measures of $\bar{r}_s$. Histogram shows number of divisions with $\bar{r}_s$ values significant at the 90% level. Numbers in parenthesis refer to the median $\bar{r}_s$ value taken over the 60-division grid. Dashed line represents 90% field significance under the assumption of independence.

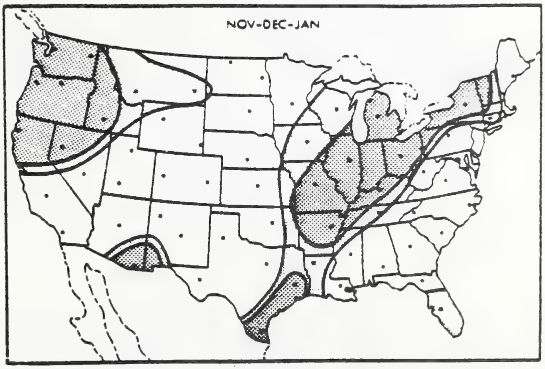


Fig. 7. Spatial distribution of $\bar{r}_s$ for the three month season, November through January. Light and heavy shading denote $\bar{r}_s$ significant at the 90% and 95% levels, respectively.

Fig. 10. Spatial distribution of $\bar{r}_s$ for the three-month season, November through January. Light and heavy shading denote $\bar{r}_s$ significant at the 90% and 95% levels, respectively.

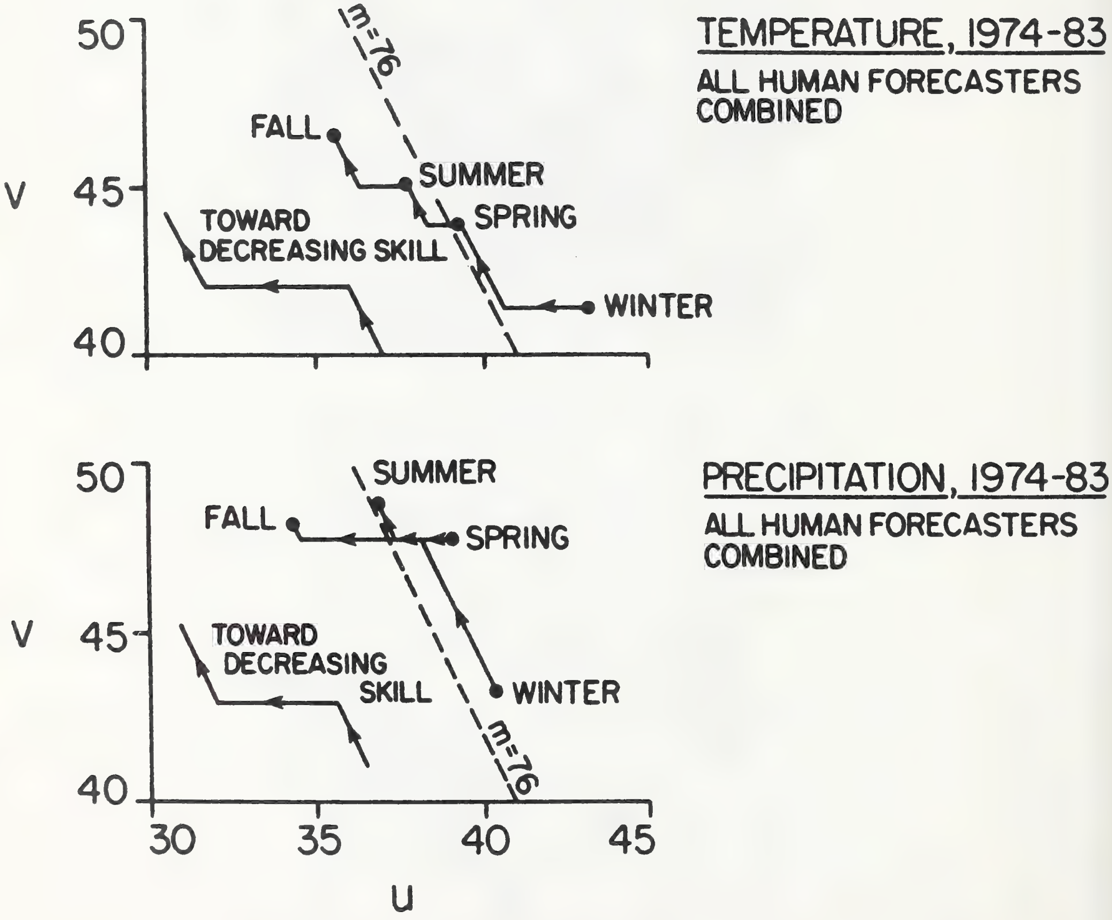


Fig. 11. Seasonal forecast skills for the human forecasters, as determined by Preisendorfer and Mobley (1984).

SUMMER FQ C. PLAINS
vs
SPRING 70 kPa ANOMALIES

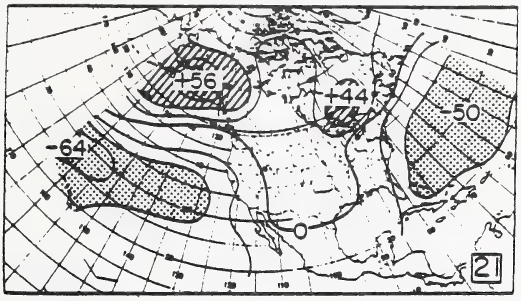
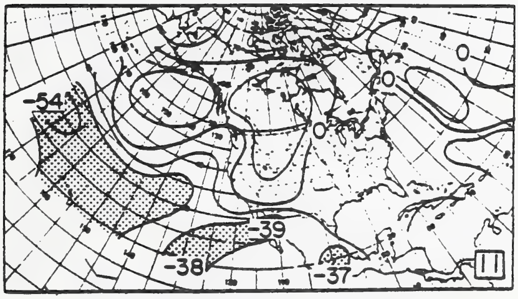

+56
+44
-50
-64
0
21

Fig. 12. Lag correlation between spring 700mb height anomalies and subsequent precipitation in the Central Plains. Period of analysis 1951-80.

AUGUST FQ TUCSON
vs
AUGUST 70kPa ANOMALIES


0
0
-54
0
-39
-38
-37
11

AUGUST FQ SOUTHWEST
vs
AUGUST 70kPa ANOMALIES

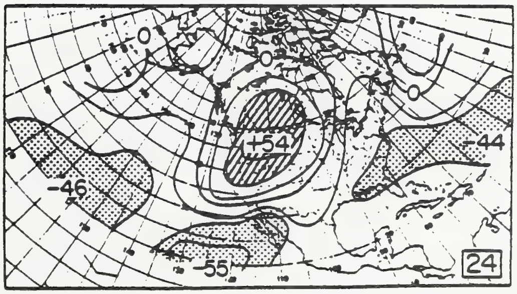
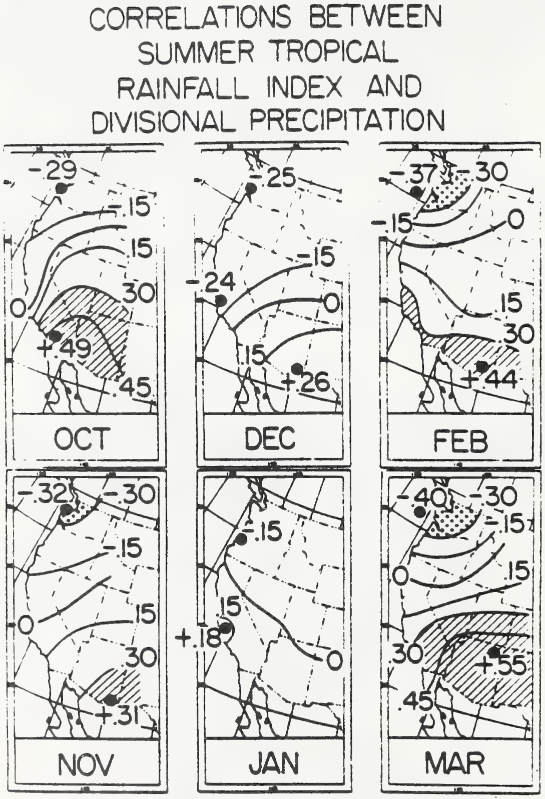

0
0
0
+54
-44
-46
-55
24

Fig. 12. Correlation between precipitation frequency and 700mb height anomalies using Tucson (top) and Southwest (bottom).



CORRELATIONS BETWEEN SUMMER TROPICAL RAINFALL INDEX AND DIVISIONAL PRECIPITATION

-.29
-.15
.15
.30
0
+.49
.45
OCT
-.25
-.15
-.24
0
.15
+.26
DEC
-.37
-.30
-.15
0
.15
.30
+.44
FEB
-.32
-.30
-.15
0
.15
.30
+.31
NOV
-.15
.15
+.18
0
JAN
-.40
-.30
-.15
0
.15
.30
+.55
.45
MAR

Fig. 13. Correlation between Wright's Tropical Rainfall Index for the Equatorial Pacific and rainfall in the western United States. High index values represent El Niño conditions.

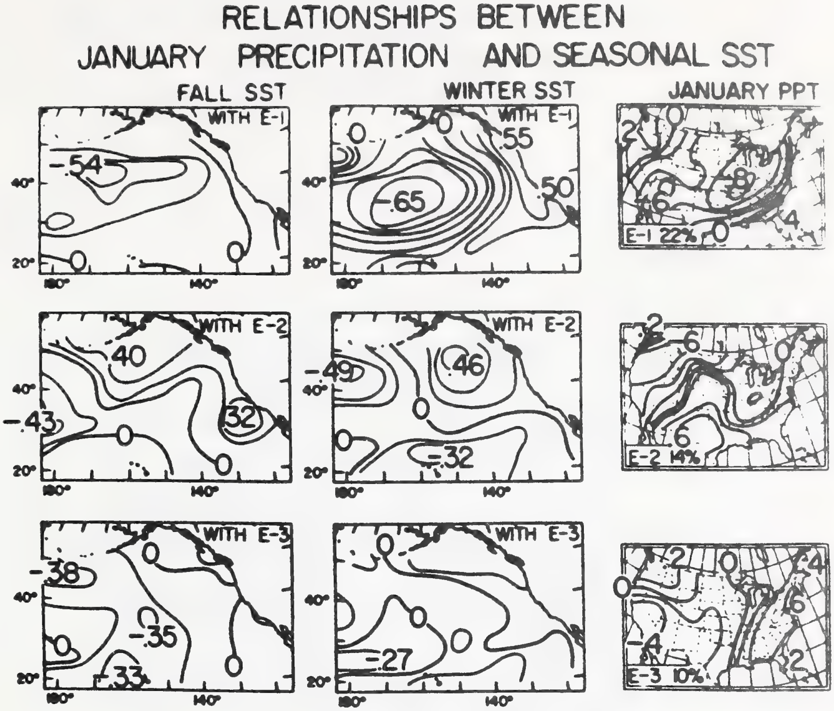
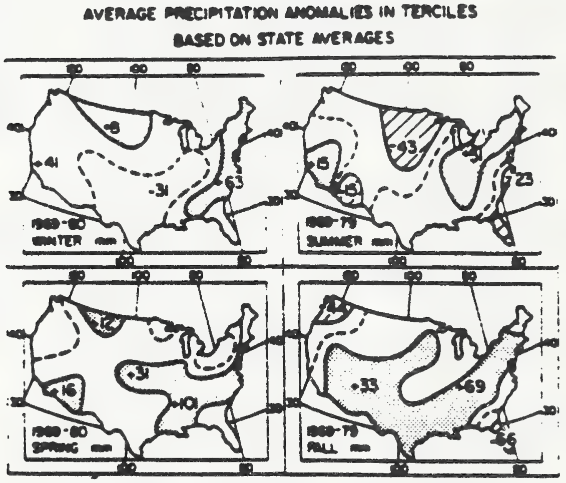

RELATIONSHIPS BETWEEN
JANUARY PRECIPITATION AND SEASONAL SST
FALL SST
WINTER SST
JANUARY PPT
WITH E-1
WITH E-2
WITH E-3
-.54
-.65
.55
.50
.40
-.43
.32
-.49
.46
-.32
-.38
-.35
-.33
-.27
E-1 22%
E-2 14%
E-3 10%
40°
20°
180°
140°

Fig. 14. The first three eigenvectors of continental precipitation for January. The percent variance explained by each eigenvector is given in the lower left of each map. The time coefficients of each eigenvector have been cross-correlated with gridded North Pacific sea surface temperature (SST) for the current and antecedent seasons. Note that with E-1, dry conditions (wet) in the central United States are associated with persistent cold (warmth) in the central North Pacific from Fall to Winter. Dry conditions in the Pacific Northwest (E-2) are associated with persistent warmth in the Gulf of Alaska from Fall to Winter. Period of analysis 1947-78.


AVERAGE PRECIPITATION ANOMALIES IN TERCILES BASED ON STATE AVERAGES

1969-80
WINTER mm
1969-79
SUMMER mm
1969-80
SPRING mm
1969-79
FALL mm
-8
+41
-31
63
-43
+15
23
-12
+16
-31
+101
+33
+69
-66
120
100
80
40
30

Fig. 15. Average seasonal precipitation anomalies, in terciles, for winter and spring 1969-80 and summer and fall 1969-79 relative to the 1947-66 period. Shaded areas indicate regions where average precipitation departures fall into above normal (stippled) or below normal (hatched) classes. Class limits are for the current normal period 1941-70. Centers of major seasonal anomalies are labeled in mm.

ABSTRACT

Integrated Agriculture and Wildlife Management

Robert Andrews
Director of Wildlife
Alberta Fish and Wildlife Division

Early settlers arrived in Alberta to find a land that contained an untapped potential for agricultural development, as well as a wealth of wildlife resources that provided the essential sustenance enabling the establishment of their agricultural operations. Through the years the agricultural industry expanded dramatically and became an integral part of the social and economic base of Alberta. Agricultural practises such as clearing, cultivating, irrigating, changing watercourses, draining, and livestock grazing all modify wildlife habitat to various degrees. Some modifications have been beneficial to certain wildlife populations but generally the intensification of agricultural practises in recent decades has been detrimental to wildlife over a great deal of the province. Increasing demands on the wildlife resource as a result of an expanding provincial population in combination with the impact of agricultural interests on wildlife habitat has resulted in decreased acceptance of the compatibility of wildlife production in agricultural areas. Serious competition has occurred between wildlife and livestock in several areas of the province. As well, wildlife managers have found it increasingly difficult to sustain wildlife populations that require habitat in the midst of farmland. Many wildlife populations are severely depressed. Wildlife and agricultural managers must cooperatively follow the principles of wise use of agricultural land to prevent soil erosion, to promote stability of both the surface and subsurface moisture regime and to maintain soil that will ultimately benefit both the agricultural and wildlife resources.

This paper examines the conflicts that occur between agricultural and wildlife interests, the competition between wildlife and livestock, and explores the potential for alternate uses of agricultural lands that will promote the compatibility of wildlife and agricultural production.

Integrated Agriculture and Wildlife Management

Robert Andrews
Director of Wildlife
Fish and Wildlife Division
Alberta Forestry, Lands and Wildlife

Western Provinces Conference on the Rationalization
of Soil and Water Research and Management
dealing with
Moisture Management in Crop Production
in 1986

86/11/10

Integrated Agriculture and Wildlife Management

Robert Andrews
Director of Wildlife
Alberta Fish and Wildlife Division

Thank you Mr. Chairman, ladies and gentlemen. It is indeed a pleasure to have this opportunity to speak to you on Integrated Agriculture and Wildlife Management.

Looking over the topics of other papers presented at this conference, the subject matter of my presentation may appear to be somewhat out of context. Other papers refer to drought and water or soil management with direct implications on the agricultural industry. With this presentation I ask that all of you broaden your scope as professionals with the realization that moisture, moisture management, and, indeed, almost all management activities that are practised in the interests of agriculture have far-reaching effects on interests and jurisdictions other than direct agricultural production.

Since settlement of this province began, farming and ranching have been important aspects of life in Alberta. Early settlers arrived to find a land that offered an untapped potential for rich agricultural production. The endless miles of grassland on the prairies were ideal for the establishment of the ranching industry, and when plowed the land proved to be fertile and grain farming commenced. Slowly at first, the landscape was altered as the agriculture industry established a foothold. Through the years, breaking of new land continued northward through the parkland region of the province as land was cleared and adapted for agricultural purposes.

All these farming and ranching activities modified the habitat formerly occupied by an abundance of wildlife species in Alberta. In some cases the modifications were detrimental to wildlife. The antelope now had to contend with grazing cattle and fencelines, and some of their natural grassland range was obliterated for grain production. On the other hand, some agricultural activity was beneficial to wildlife populations. In the parkland and forested regions, some agricultural clearing, combined with light grazing and a mixed farming operation has, in the past, provided good habitat for species like the white-tailed deer.

There is no doubt that there was also a certain degree of wildlife-agriculture conflict experienced by early farmers. Ranchers near the foothills found that the grizzly bear and the wolf could be detrimental to cattle production. Coyotes harassed sheep populations and foxes took advantage of poultry in farmyards. However, early settlers used, and largely depended on, the wildlife resource as a food source and in the pioneering spirit they accepted the occasional conflict as one of the challenges, or the risks of establishing an agricultural operation. With minor exceptions, early agricultural efforts and the production of wildlife were compatible.

However, in recent decades agricultural efforts have intensified. Efforts have been concentrated on maximizing production on nearly all farmland. Agricultural land dominates the landscape over large areas of the province with continuous tracts of farmland stretching to the horizon. The trend has been away from the small mixed farm to large mono-culture operations. Land that was once attractive to wildlife is rapidly disappearing. In the interest of more efficient farming practises, scrubby fencerows and shelterbelts have been cleared. Many potholes and sloughs have been drained or filled. Near those waterbodies that have not been drained or filled, the land is cultivated to the water's edge, effectively destroying the wetland productivity for wildlife. Irrigation systems are being upgraded and in the process more valuable wildlife habitat is lost. Seepage areas along irrigation canals are being eliminated and the brushy ditch banks are being cleaned up. The intensification of irrigation has also caused vast expanses of natural prairie grassland to be converted to crop production.

The end result of this accelerated modification of the natural environment is that the coexistence of agriculture and wildlife is seriously threatened. Wildlife habitat within agricultural areas has been degraded to the point that in many areas of the province wildlife deserts exist. Many wildlife populations are severely depressed and where viable populations do exist, we are in an era of substantial competition between wildlife and agricultural interests.

Conflicts between livestock producers and ungulates are becoming increasingly prevalent. The primary production areas for cattle in Alberta exist along the foothills of the east slopes and throughout the remaining grassland of the southern portion of the province. Unfortunately, these same areas are critical to the survival of pronghorn antelope, mule deer and elk populations. Native prairie has been reduced by conversion to grain production and the remaining grassland is heavily utilized for grazing of livestock. This is the essential habitat required by antelope and mule deer and intense grazing eliminates the availability of forage for these species. This problem has been intensified during the recent several years of drought with the reduced natural productivity of the grassland. As a result we have experienced greater numbers of conflicts with mule deer and antelope in grain and forage producing areas as the competition for natural vegetation increases. Similarly, conflicts exist in cattle producing areas along the foothills. In this case cattle are grazing in the natural elk winter ranges and in some cases elk winter ranges have been converted to tame hay production. Again, the drought conditions we have experienced illustrated the degree of direct competition that exists. Production of vegetation on some ranges has been reduced to the point that cattle grazing has left little surplus to sustain wildlife populations through the winter. Elk have been forced to leave the overgrazed foothills and have congregated on open ranchland where considerable damage has occurred to ranchers' haystacks. The range has supported cattle all summer and cannot support elk during the winter.

Throughout the parkland and the agricultural area of northern Alberta ungulate habitat has been reduced, through clearing, to bushland along watercourses and other steep, or poor quality non-arable lands. These areas, that cannot be cultivated, are also utilized by cattle producers with the same results. The diversity of forest cover and mixed farm operation that is optimal for white-tailed deer has been destroyed by intensive farming and grazing and drought conditions have forced deer out of natural areas into farmers' crops and haystacks.

Ranchers that graze cattle in the forested areas of the foothills and the northern forest fringe also experience direct losses to predators. Most losses are caused by wolves who learn that domestic livestock are easier to catch than wild ungulates.

Bears also cause injury or death to some livestock but their major impact is in the form of damage to apiaries. Apiarists traditionally place their beehives in bush areas near cultivated fields. These areas are often near watercourses or are fingers of forested lands extending into the cultivated areas and are natural travel corridors for bears.

Direct competition also occurs between agricultural interests and the production of pheasants and other upland bird species. Intensive farming practises have eliminated fencerows, old farmsteads and small shelterbelts that were upland bird "reservoirs". Pheasants and other upland birds utilize these areas as winter food sources, nesting cover and for protection from the inclement winter conditions. The sterile environment associated with extensive tracts of land used for mono-culture grain production leaves little room for pheasant and grouse production. The old irrigation systems with weed-choked ditch banks and associated small wetlands caused by seepage were ideal habitat for upland bird production. However, the move in recent years to upgrade these irrigation systems and improve the efficiency of water delivery has also eliminated a great deal of upland bird habitat. Likewise, intensive grazing of grassland has had a similar detrimental effect on bird populations. Although this type of competition, or conflict, has not resulted in a direct economic loss to agricultural producers, the effect on the survival of upland bird populations has been severe.

One of the more important wildlife-agriculture conflicts is the ongoing battle between grain producers and waterfowl populations. Wetland complexes with associated ungrazed areas of shrub and/or grassland are ideal duck production areas. In the fall, waterfowl produced on these areas congregate, or stage, on larger waterbodies that are used during migration. Grain production in the vicinity of waterfowl staging or migration waterbodies create potential for agricultural losses due to depredation. The amount of damage occurring in any year is directly related to the length of time crops remain in the swath. Any adverse weather that delays harvesting will result in increased damage, with losses in the millions of dollars not uncommon. In recent years there has been an alarming trend towards elimination or degradation of waterfowl habitat. The concerted effort to maximize agriculture production has resulted in the drainage or filling of a great deal of wetlands. The recent drought conditions we experienced have accelerated that practise and we are at the point where there are very few wetlands in settled Alberta that have not been impacted by agriculture. Those areas that have not been drained or filled are cultivated to the water's edge eliminating critical nesting habitat. As a result of this practise across the prairie provinces, North American duck populations are in trouble. Man-made changes in land use are largely responsible.

The number of areas where there is direct or indirect conflict between agriculture and wildlife are seemingly endless and I could go on and on. However, from the few that I have mentioned I hope I have illustrated that we have progressed from the situation where agriculture and wildlife coexisted, with enough so-called "wasteland" available to produce wildlife, to the point where the demands placed on the limited land and water resources over much of this province exceed the capacity to produce both wildlife and agricultural products without serious conflict.

Over the years a number of programs have been implemented in an attempt to decrease the degree of conflict between agriculture and wildlife. Some programs are preventive, others are reactionary and some attempt to partially compensate for agricultural losses to wildlife.

The responsibility for the control of predators comes under the jurisdiction of both Alberta Agriculture and the Fish and Wildlife Division. Alberta Agriculture retains the responsibility for the control of coyotes within the agricultural areas of the province while the control of coyotes in non-agricultural areas, as well as the control of wolves, bear and cougar, is the responsibility of the Fish and Wildlife Division. In all cases of predator related losses the producer is encouraged to utilize farm management techniques that minimize the potential for losses. However, if losses do occur, attempts are made to remove the animals responsible. In the case of coyotes within the agricultural areas, attempts are made to remove the coyotes using coyote-getters, strychnine baits, traps and snares, or by shooting. With all predators outside of the agricultural area, attempts are made to remove the predator utilizing strychnine bait, traps or snares. Bears are either killed or relocated, with particular efforts at relocation made in the case of grizzly bears. Alberta Agriculture also administers the Livestock Disaster Predator Indemnity Program which compensates producers up to 80 percent of the commercial value of livestock lost to predators.

The Alberta government has also worked with beekeepers in developing an effective fencing program to reduce bear damage to beehives. This effort has progressed to the point where compensation, is provided only where the damage has occurred to beehives that are within a functioning electric fence.

A number of alternatives have been attempted to alleviate the conflict of ungulates in haystacks. The Fish and Wildlife Division has provided scaring materials and repellents to landowners experiencing this problem. We also provide fencing material to the landowner who is then responsible for erecting the fence around his stacked hay. In areas where haystack damage is a chronic problem recreational hunting seasons have been modified to discourage ungulate use of stacks. In some extreme cases ungulates (elk) have been trapped and relocated to alternate areas of the province. The drought depleted natural range and the severe winter of 1984/85 also prompted the initiation of intercept feeding where ungulates (deer, elk and antelope) were fed commercial feed in an attempt to keep them out of haystacks and to prevent winter die-offs.

In respect to grain producers, a compensation program exists that reimburses the farmer for wildlife damage to unharvested crops. This compensation program is designed to reimburse the farmer for his actual cost of crop production. The portion of this compensation program that pays for waterfowl depredation is cost-shared by the federal and provincial governments.

The federal and provincial governments also conduct a waterfowl damage control program designed to prevent waterfowl depredation on cereal grain crops in the most severe depredation areas.

It is clear that intensive management of agricultural land has progressed to the point where, in many cases, there is no room for wildlife. The habitat necessary to maintain viable wildlife populations has been lost over the past several decades. Some of this loss occurred in insignificant increments and has been occurring for years. Some is recent and obvious, some is the result of improving technology and much as been encouraged by various incentives and economic pressures. It is obvious that the coexistence of agriculture and wildlife is seriously threatened in some areas.

Sometimes practises which are detrimental to the long-term welfare of the resource base are done, not out of ignorance, or unknowingly, but for short-term economic gain. It should be clear to professional managers that the very basic ingredients of life - the soil and water resources - require our immediate attention if we are to retain the quality of life that we have found acceptable. Too often in the past, "develop" or "improve" has meant "new use" and conversion has been to "single use" to the detriment of all other or former uses. It is time to realize that this attitude is outdated and as resource managers we must double our efforts to maintain the resources we have. As with other civilizations, we will also be judged on how well we have managed and conserved our land and water resources.

Perhaps it is time to closely examine the land that has been "developed" or "improved" for agricultural production. From a land management perspective, is that the best use for that land? Perhaps we, collectively, should be striving to develop uses that are more compatible with the land's capability rather than attempting to modify the land to fit the mold of our desired uses.

During the course of this conference I am sure you hear much about the tremendous importance of water. Wetlands are certainly valuable for wildlife production but their values extend beyond that. The values and benefits of wetlands include moisture retention, groundwater recharge, drought resilience, flood prevention, erosion control, biological breakdown of pollutants and are an essential base for the evaporation-precipitation water cycle. We need wetlands as one of the major components of the ecosystem. Any modification of the land base that involves clearing and cultivation affects the watershed and ultimately leads to the necessity of actively attempting to manage lands under an unnatural moisture regime. Perhaps we should instead be developing land uses that do not require drastic alteration of the land base.

The Alberta government is examining the feasibility of legalizing game ranching of ungulates for meat production. A second discussion paper has been recently distributed which deals with the issues and concerns expressed by the public with respect to game ranching. The concept of game ranching certainly provides food for thought in respect to alternate uses of the land base. Ungulates are better adapted to survival in the natural environment than domestic livestock and, on marginal farmland, can produce more biomass than livestock. This is one example of a potential land use that does not necessarily require the total modification of the land and water base.

Another new wildlife management initiative that is geared directly towards preservation of wetlands is the recently signed North American Waterfowl Management Plan (NAWMP). Earlier I mentioned that North American duck populations are in trouble. The NAWMP, which is the culmination of several years of international planning, is the formal recognition that North American wetlands have declined in number or have been degraded to the point that they no longer can maintain traditional duck populations. The Plan points directly at the prairie and parkland areas of the three prairie provinces where 40-45 percent of the continent's ducks are produced. In some years Alberta holds 20 percent of the continental spring breeding duck population. The extended dry period across most of the North America Great Plains has wreaked havoc with waterfowl habitat and Alberta is no exception. In fact, the situation in this province has probably deteriorated more than in most other areas.

The NAWMP formally gives international recognition to the importance of the land and water base as the places which not only support, but are essential to populations of wild animals. This is not the first recognition of the importance of wetlands. Ducks Unlimited was one of the earliest groups to recognize the importance of Canadian wetlands, in the 1930's. Even they were preceded by the Refuge Branch of the U.S. Fish and Wildlife Service which was 50 years old in 1984. Similar rather recent formal recognition has occurred within Canadian governments. In 1981, Saskatchewan announced their Heritage Marsh program; in 1982 Alberta endorsed the Wetlands for Tomorrow program, and last year Manitoba adopted their Heritage Marsh program. Also in 1984 a private foundation, Wildlife Habitat Canada, was officially unveiled, dedicated to wildlife and wetland habitat conservation. These programs, by themselves, will not rectify the prairie habitat problem nor will they guarantee an adequate supply of ducks, but they do represent formal government recognition of the value of wetlands and are a definite signal that special programs are required.

The NAWMP proposes that up to $1 billion be spent in Canada on a 15-year habitat conservation program. It recognizes that:

a) the land use practises of the landowners are the key to wetland conservation;

b) sound farm soil and water conservation practises benefit both wildlife and agricultural production;

c) farmers should be reimbursed for employing land use practises that provide for wildlife and wildlife production; and

d) habitat conservation programs should be on a voluntary basis.

The plan also identifies the relative sharing of the costs of this joint venture. Of the $460 million expenditure identified for Alberta, it is anticipated that 75 percent would come from U.S. sources.

The benefits of a relatively high, stable waterfowl population to Albertans would be immense. It is estimated that, in a year of good populations and high participation by hunters, the recreational value of waterfowl hunting to Albertans approaches $39 million.

Of equal importance to the recreation and tourism aspects are the benefits to be derived by farmers and ranchers.

Firstly, a pre-requisite of any program of this magnitude will be the minimizing of farmer concerns regarding wildlife damage to crops. The program will contain provisions for increased compensation for losses. The negative aspects of the presence of ducks will be eliminated as far as possible before any large scale habitat program is initiated. We cannot expect grain producers to be enthusiastic about the program until ducks and geese no longer represent a hazard or a liability. To this end, the Fish and Wildlife Division presented a formal brief to the Alberta Crop Insurance Review Steering Committee this past September. That brief recommends a compensation program which provides farmers with full reimbursement for all losses caused by wildlife.

Secondly, the bulk of the dollars to be spent intensively managing a million acres of breeding habitat in Alberta will be channeled directly into the farming economy. The majority of the habitat gains will be in the form of land use contracts, a method of paying landowners to provide set-aside areas and to manage less productive agricultural lands for wildlife.

I would also reiterate that 75 percent of the dollars to be spent on this program are to come from U.S. sources. The Alberta economy would gain significantly from the infusion of U.S. dollars.

In summary, this plan identifies the following:

a) International recognition that hunting and non-hunting use of wildlife has high economic value as a major resource base for tourism.

b) International recognition that wetlands and associated upland habitats have great value, they are declining, and are in trouble. They provide a variety of benefits and must be retained for a variety of uses; in general, a change in how wetlands are perceived.

c) Recognition that the negative values associated with wildlife are a force to be dealt with, a legitimate wildlife management problem.

d) Formally recognizes the importance and contributions of privately-owned land in general, and farmers in particular, in supporting wildlife resources. Many land use decisions which have adversely affected wildlife and/or wildlife habitat have been economic decisions based on anticipated dollar returns. Wildlife has not been able to successfully compete economically, with many other land and water uses. Privatization of some of these economic opportunities may place the user of the wildlife resource in the tourist role with respect to landowners.

e) Recognizes the need to make the production of wildlife on private land at least a break-even proposition for the landowner, if not a profitable one. Wildlife can become an important part of a diversified economy for many landowners.

I view the NAWMP as an extremely large step forward for Alberta and Canada. The benefits to be gained from this international agreement extend far beyond wetlands and ducks. To me it not only dispels the myth that the wildlife resource is unlimited but, more importantly, it signifies a genuine concern for land and water resources and a healthy environment.

In conclusion, I have attempted to demonstrate the effect that intensified agricultural practises have had from a wildlife managers' viewpoint. I have described several areas where there is direct competition and conflict between agricultural and wildlife interests in their requirements for the same land and water base and some of the programs that have been developed to minimize the effect of these conflicts. I have also attempted to outline a couple of wildlife management initiatives that endeavor to foster the compatibility of agriculture and wildlife production on the same land resources. We, as land, water, and wildlife resource managers face an important and demanding challenge. We must, collectively and co-operatively, promulgate integrated programs that will require the input, support and commitment of a wide range of individuals, jurisdictions and agencies, which will benefit all North Americans through sound land and water management practises for all users of those resources.

Thank you for your attention ladies and gentlemen, and for the opportunity to make this presentation at this conference.

FIELD CROP MANAGEMENT AND INNOVATIVE ACRES

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Abstract

The Innovative Acres Program was initiated in 1981 to test, in a farm setting, management techniques that had resulted in increased yields and water use efficiency on small plots. The program involves approximately 40 farm cooperators and many research specialists of various backgrounds. The major objective of the Innovative Acres Program is to maximize crop production through the use of water-efficient, soil conserving practices. To achieve this objective, the cooperators have established field rotations to test innovative farming practices including snow management techniques, chemical fallow and high rates of applied fertilizers. The results of the Innovative management system are compared to results obtained from adjacent fields farmed using the regular farming practices for that soil and climatic zone. This paper discusses the results obtained during the period from 1981 to 1985, draws conclusions, and offers suggestions based on the data.

FIELD CROP MANAGEMENT AND INNOVATIVE ACRES

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The Innovative Acres Program was initiated in 1981 to test on a field scale and in real farm situations the applicability of experiences gained on research plots. These experiments indicated that in the drier areas of the Prairies:

1. fertilization at recommended rates would increase yields of fallow and stubble crops without increasing total water use, i.e. water use efficiency was increased.
2. the portion of the annual precipitation that is cycled through the crop increases as the frequency of summerfallowing decreases, i.e. the conservation of precipitation received during fall, winter, spring and, in particular, during the summer is very low on summerfallow fields.
3. summerfallowing was a major factor in soil deterioration due to accelerated organic matter breakdown and erosion.

The objectives of the Innovate Acres Program are to maximize crop production through the implementation of water-efficient farming practices, while maintaining high soil quality. The proposed farming practices have to be both practical on a field scale as well as economically sound if they are to be accepted. Innovative Acres is not a program to manage drought, its aim is to use the available water as efficiently as possible.

The Innovative Acres Program involves the cooperation of many individuals and organizations including: cooperating farmers and professional agrologists from university, government and industry. Saskatchewan Agriculture provides the major source of funding through the Agricultural Development Fund and the agricultural industry provides fertilizer and herbicides. Funding from other agencies, in particular the Natural Sciences and

Engineering Research Council, supports closely related basic research in the areas of N_2 fixation and soil erosion.

In 1981, 27 farm cooperators started with the Program, this number has since increased to 40, located in all areas of Saskatchewan. Each farmer provides two adjacent fields of 40 acres or larger for the comparison of innovative (INN) and regular (REG) cropping practices. In each field 12 benchmark sites (approximately evenly distributed between upper, middle and lower slope positions) are sampled for soil moisture and yield. The INN fields are managed for optimum water efficiency through practices such as:

1) snow management in combination with high fertility
2) chemical fallow or partial fallow systems
3) use of winter wheat in rotations.

Small plot and field strip tests have been conducted to investigate:

4) fertilizer (N, P, K, Cl) responses of different small grains in relation to slope position
5) N_2 fixation by legumes and their possible role in crop rotations.

In the following sections we briefly describe some of the highlights of the Program, as well as discussing some of the problems that were encountered.

Snow Management

The following techniques are used to trap snow:

(a) fall-applied herbicide to eliminate the need for tillage after the harvest (most farmers used 2,4-D)
(b) stubble management through the use of deflectors, strippers, high-low swathing, and straight combining.

Table 1 shows the overwinter soil water gains that were obtained from differing fall stubble management methods. The data confirm the well known fact that fallowed fields gain very little additional soil water during the winter. At first glance the different fall

Table 1. Overwinter soil water recharge following the use of differing methods of fall stubble management.

Treatment	No. of tests	Soil water gain (cm)
Cultivated fallow	51	0.7
Cultivated stubble	48	4.0
Undisturbed stubble	112	4.7
Undisturbed stubble with strips	42	4.9
Winter wheat seed directly in stubble	14	5.7

stubble management methods appear to have little effect on overwinter recharge, but this is misleading as these fields were located all over Saskatchewan and were not all sampled at the same time. A better comparison is obtained by comparing adjacent fields and looking at the difference in recharge (Table 2). Although the differences in soil water recharge due to fall stubble management are small, they result in yield increases of 5 to 20% (Table 3).

Table 2. Overwinter soil water recharge on adjacent field having different stubble management.

Undisturbed stubble vs.	No. of pairs	Difference in soil water recharge (cm)
Cultivated fallow	23	4.3
Cultivated stubble	24	1.1
Stubble plus strips	22	-0.6
Stubbled in winter wheat	4	3.7

Table 3. Increases in wheat yields on adjacent fields due to differences in fall stubble management (average of six sites).

Slope position	Yield (kg/ha) Cultivated stubble	Yield (kg/ha) Managed stubble	Additional overwinter recharge on stubble (cm)
Upper	1735	1915	0.9
Middle	1990	2390	1.5
Lower	2150	2290	1.4

These yield increases are obtained at little extra cost to the farmer. The largest increases in yield are obtained on the mid slope positions, even though the lower slopes received comparable levels of soil water recharge.

From the results obtained to date, it appears that relatively simple stubble management techniques can increase overwinter soil water recharge by 1 cm or more. The results are quite variable and depend on many factors, e.g. the amount of snow received and fall moisture conditions. In the Brown soil zone, the supply of soil water in the spring will often be inadequate for continuous cropping, even if stubble sculpturing is used. The potential for snow management increases going from the Brown to the Dark Brown and Black soil zones but problems associated with infiltration of the meltwater become more frequent in these zones. In the drier areas further work is required to improve methods of snowtrapping, but elaborate practices are probably not economically justifiable. In the wetter areas, many farmers are hesitant to adopt snowtrapping methods since they fall cultivate to minimize the time required for seedbed preparation in the spring. In the wetter areas elaborate snow management systems may be economically feasible. For example, snow and snowmelt water could be collected in a few large sloughs and used for supplemental irrigation in the summer.

Chemical and Partial Fallowing

The effects of chemical and regular fallow methods on water conservation and NO_3^--N buildup were compared at 12 sites. No differences were observed in the soil water recharge under both fallow systems. During the fallow summer, the buildup of NO_3^--N in the soil was nearly always less under the chemical than under the regular fallow system. The average difference from 11 sites was 23±19 kg/ha. Some NO_3^--N was often lost during the second winter period, but at seeding time the difference between the soil NO_3^--N levels of the two systems remained constant. Yields on the chemical fallow were similar, or perhaps somewhat lower, than on the regular fallow. Costs associated with chemical fallow were 2 to 3 times that of regular fallow (Table 4), partly because many of the cooperators were exposed to this technique for the first time. In the wetter regions of the province the cost associated with chemical fallow are excessively high.

Chemical fallow showed clear advantages of soil conservation in terms of controlling wind and water erosion. Estimates of straw residue at four farms in 1985 confirm that straw losses are substantially lower under chemical fallow than under regular fallow.

Table 4. Average costs of chemical and regular fallow in different soil zones ($/ac).

Soil zone	No. of pairs	Chemical	Regular
Brown	5	23.40	6.90
Dark Brown	5	29.00	12.80
Black and Gray	4	46.00	20.00

Two systems of partial fallow have been tested at a few sites:

1) reducing the fallow period by seeding winter wheat on chemical fallow
2) growing a grain legume for the first half of the growing season.

Yields of winter wheat in chemical fallow were equal to or better than those of spring wheat planted on regular fallow the next spring (particularly in 1985 when rainfall was very low). Partial legume fallows (in this case lentils) are kept flexible: in good years the lentils are grown to maturity and harvested, while in dry years they are desiccated in July. The latter course was followed at three test sites in 1985, and the fields were then seeded to winter wheat. The data indicate marginally higher NO_3^--N levels (5 to 15 kg/ha) on the lentil fallow than on the regular fallow but substantially lower levels of soil water (approximately 5 cm). Approximately half of this moisture deficit was compensated for by recharge the following winter.

Winter Wheat

Before 1985, most of the Innovative Acres work on winter wheat was conducted on small plots for the purpose of investigating the optimum time, form and rate of fertilizer N application. In the fall of 1984, 11 INN and 5 REG fields were planted to winter wheat. That winter half the fields and half the small plots winter killed. The average yield obtained from the remaining fields was approximately 2000 kg/ha, and in general the yields were higher than those obtained from spring wheat. In the fall of 1985, 7 fields were planted to winter wheat and all survived, but four of the fields were infected with rust which reduced their yields by 10 to 80%.

Based on the limited experience with winter wheat in the Innovative Acres Program, this crop seems to be best suited to the drier areas where rust is less of a problem and where crop selection is limited. Winter wheat is normally sown in stubble, but appears to perform well on chemical fallow. In the latter case, winter wheat can reduce erosion, which is normally a hazard on fallow fields just prior to, and particularly after, seeding.

Fertilizer Management

Although the earlier work conducted in Saskatchewan had clearly demonstrated that fertilizers applied at recommended rates increased crop yields, some aspects of fertilizer management were included in the Innovative Acres Program. In attempting to interpret the results of these trials, it is important to remember that the program is conducted on fields that have received high management input including fertilizers for a number of years.

Phosphorus

Many of the cooperators left zero-P check strips in their fields, and in 1983 there arose some concern about low or no P responses in stubble seeded wheat fields. It was reasoned that this could possibly be due to increased mycorrhizal infection on stubble seeded fields. To further investigate this, additional zero-P check strips were included at most sites in the 1985 program. Yields were obtained by sampling 10 or more adjacent 1 m^2 sites from the P fertilized field and the 0 phosphorus check strip. Most of the results on fallow-seeded crops were obtained in 1984 and 1985 which were dry years, therefore, the data set was augmented with results from similar tests conducted in 1977 under the Palliser wheat production program.

The data in Figure 1 clearly shows that there is a better probability of a yield increase to seed-placed P on fallow than on stubble fields. The responses on stubble are more erratic than on fallow, with a greater probability of obtaining a low response. Simple linear regression analysis indicated no relationship between yield response and the level of applied P_2O_5 on fallow or on stubble. Although statistically not significant, yield increases are more likely at low soil test-P levels (Figure 1). Check and fertilized yields were highly correlated. Yield increases were not significantly related to check yield, but were correlated ($P > 0.05$) with fertilized yields with the regression accounting for only 10 to 20% of the observed variation in yield response.

The yield responses to applied P were normally distributed (Figure 2). The probability that a certain magnitude of response will be obtained can be used in a preliminary economic assessment of the data. For example, the average amount of P_2O_5 applied in the stubble and fallow tests was 30 kg/ha at an approximate cost of $18/ha. Figure 2 indicates that there is a 15% probability that the farmer would have recovered his fertilizer costs on either fallow or stubble, if wheat is priced at $3/bu. For $5/bu wheat the breakeven probabilities are 40 and 30% for fallow and stubble, respectively. Lower rates of seed placed P would be more economical and, as mentioned earlier, within the range of rates used (about 15 to 45 kg/ha of P_2O_5), there was no significant effect of rate on yield response. At the 15 kg/ha P_2O_5 rate, the breakeven probability for $3 wheat would be in the order of 50 and 30% for fallow and stubble, respectively. This type of analysis does, of course, not take into account other important benefits from P fertilization such as its effect on crop maturity and quality.

Potassium Chloride

In 1985, 32 strip trials were carried out which involved the addition of chloride fertilizer (KCl) to various crops. Ten significantly positive and two significantly negative yield responses were obtained. The reason for these different responses is being investigated further in a project dealing specifically with the effect of potassium chloride on root rot and other cereal diseases.

Nitrogen

Results of experiments on the effect of N fertilizer rate on yield are used to develop guidelines for the application of fertilizer nitrogen at variable rates within a field. Trials were conducted in 1982 and 1983, and a further study was initiated in 1985 and 1986. The results of these experiments indicate that yield gains from applied N on lower slopes are equal to or greater than gains on upper slopes (Table 5). This suggests that in the drier

Table 5. Effect of slope position on yield gains of wheat due to applied N-fertilizer (1982-83 growing season).

Soil zone	Soil association	Yield increase over check* (kg/ha) Slope position Upper	Lower	Lower-Upper
Brown	Ardill CL	525	500	-25
	Ardill CL	495	640	145
	Ardill CL	370	835	465
	Ardill CL	150	275	125
	Ardill CL	-410	15	425
	Amulet CL	1340	1360	20
	Sceptre HvC	1060	1410	350
Dark Brown	Weyburn L	740	1710	970
	Weyburn L	870	1200	330
	Brooking CL	-30	940	970
	Keppel L	370	350	-20
	Average	510	840	340**

* Yield at 50 kg N, 30 kg P_2O_5/ha - yield at 5 kg N, 30 kg P_2O_5/ha

** Significantly >0 at 1% probability level

regions of the prairies, higher N-fertilizer rates should be applied to the lower rather than the upper slopes even though the lower slopes may already have the highest level of soil NO_3^--N. In areas of higher precipitation the reverse may be true. Clearly, the concept of variable rate fertilization must take into account not only the variation in soil fertility but also the variation of moisture availability within the field unit.

Nitrogen Fixation

Since few estimates were available on the fixation of atmospheric nitrogen (N_2) by grain legumes, a study was initiated in 1984 to determine the extent to which lentils, peas and fababeans fix N_2 in the various soil zones. Inoculated and uninoculated treatments were planted side-by-side in small plots and N_2 fixation was measured by ^{15}N dilution, and by comparison to N-uptake by wheat or barley.

Inoculation generally increased yields, although the response varied widely between sites (Table 6). The variability in the data can be attributed to several factors including the presence of indigenous rhizobia, high levels of soil NO_3^--N in the soil and drought stress. These factors also affected N_2 fixation (Table 7). The amount of N_2

Table 6. Yield response of grain legumes to inoculation (1984 and 1985).

Cultivar	No. of sites	% increase in total yield due to inoculation		
		Average	Minimum	Maximum
Eston lentils	11	35	-8	80
Laird lentils	11	18	-22	51
Trapper peas	10	15	-16	78
Tara peas	10	22	-43	99
Aladin fababeans	6	17	-20	54
Outlook fababeans	6	17	-21	76

Table 7. Yields of above ground dry matter (T/ha) and amount of nitrogen fixed (kg/ha) for lentils, peas and fababeans (1984 and 1985).

Area of province	Crop	Yield (T/ha)	N fixed (kg/ha)
South (Brown soil zone)	Lentils	0.5-1.5	5-30
	Peas	0.0-3.0	0-40
	Fababeans	0.0-0.8	----
North (Gray and Transition soil zones)	Lentils	5-8	60-80
	Peas	5-9	80-120
	Fababeans	7-10	120-160

fixation varied from 10-30 kg/ha in the Brown soil zone up to 80-160 kg/ha in the Gray and Gray-Black soil zone. This study was continued in 1986 and expanded to investigate the effects of fertility and rhizobial strains on fixation.

Agronomic Implications

The importance of water for dryland grain production in Saskatchewan is illustrated in Figure 3. The most encouraging feature of these data is that nearly all of the yields lie above the line for the 1925-1952 period. It would thus appear that water use efficiency has improved considerably since that time. Many of the yields obtained are in fact higher than those suggested by Henry in Grainews whose analysis was based on recent plot and field data. Innovative Acres field data indicates that approximately 12.5 cm of water are needed before any grain is produced and that every additional cm of water leads to a potential yield increase of 200 to 250 kg/ha. In the Dark Brown, Black and Gray soil zones, wheat yields are lower than expected from total crop water use. A number of factors contribute to this including water loss by drainage, weed and pest problems, frost damage and perhaps inadequate fertility. For example, we would expect a yield of nearly 4500 kg/ha with 35 cm water use. This yield level is close to the photosynthetically possible value for this area and 180 kg/ha N (soil - fertilizer) would be required. Not many farmers fertilize up to this level due to the unpredictability of growing season precipitation.

The exact impact of the innovative practices including snow management, high fertilizer rates, chemical fallow, winter wheat in the rotations etc. is hard to assess. One cannot simply look at the yields of spring wheat in rotations of different lengths, since the amount of precipitation received varies widely from season to season. For example, in 1982 many of the fields in the Brown soil zone grew wheat on stubble and, as the precipitation was above normal, the yields were higher than normal. By contrast in 1984 and 1985 drought and grasshoppers resulted in low yields on both stubble and summerfallow. Until we find a reliable method of adjusting yields for growing season conditions, the innovative rotations can only be assessed by comparing adjacent fields in the same year (Table 8). Since the initiation of the program wheat yields on stubble average 80% of those obtained on fallow, however, in three out of four years the stubble/fallow yield ratio was higher than 0.80, whereas in 1984 it was only 0.58. In general, innovatively managed stubble fields outyielded regular stubble fields, but the results fluctuated from year to year and from farm to farm.

Table 8. Yield ratios for spring wheat under different management systems (1982-85).

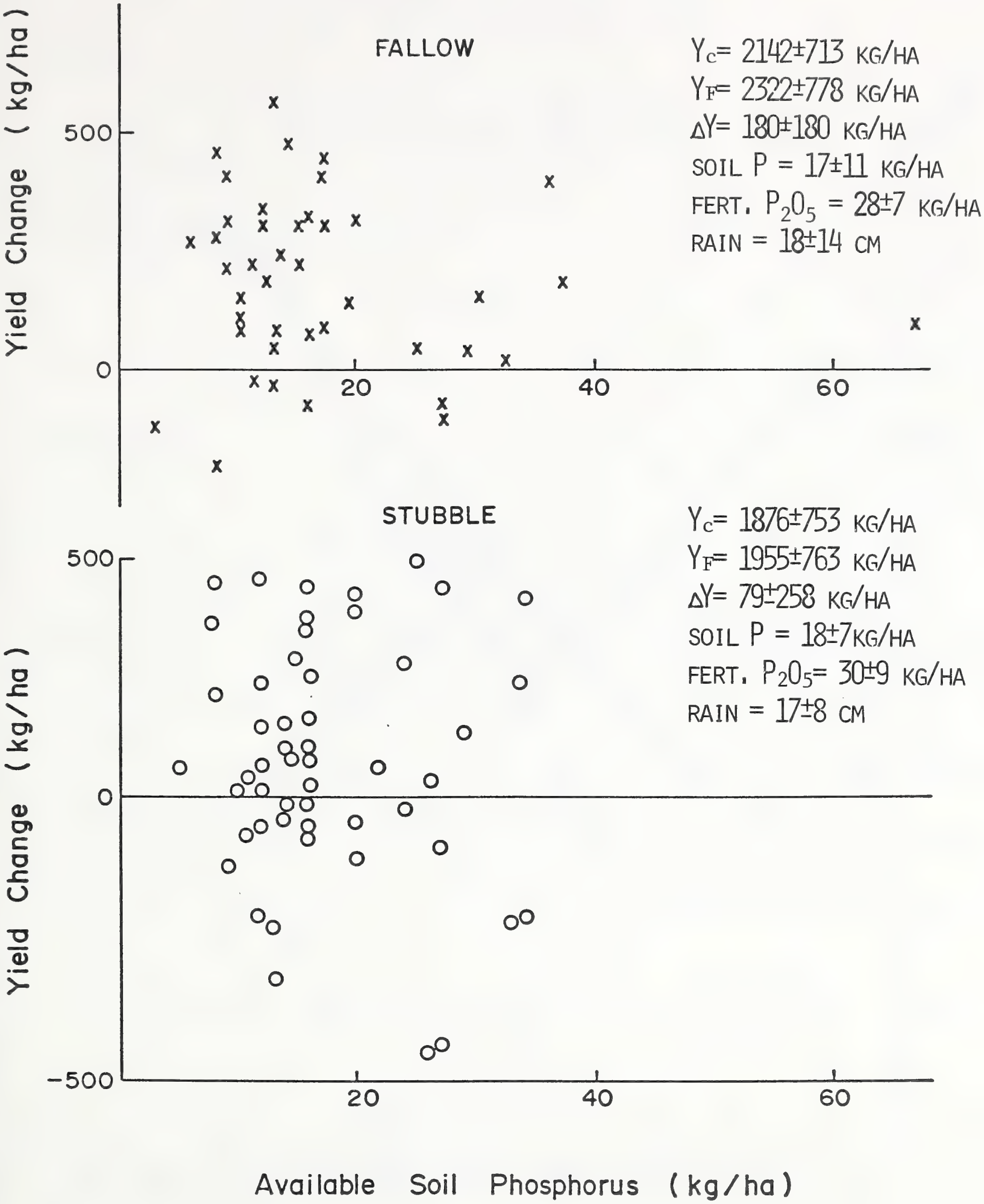
	Stubble/Fallow		Innovative stubble/Regular stubble	
	No. of sites	Yield ratio	No. of sites	Yield ratio
1982	9	0.93	7	1.02
1983	9	0.91	10	1.07
1984	11	0.58	9	1.04
1985	2	0.86	10	1.11
All	31	0.80	36	1.06

Stubble management for snowtrapping presents a cheap and increasingly practical method for increasing spring soil water supplies in the Brown and Dark Brown soil zone. The average soil water gain is, however, relatively small and varies widely from year to year. Snow management will not eliminate summerfallowing in the drier areas, but, particularly in the Dark Brown soil zone, it should substantially reduce its frequency. Farmers should strive towards more flexible rotations with the decision on whether to crop or to fallow being based on spring soil water supplies. Using simulation modelling with actual climatic data over a 16 year period, Brydon (M.Sc. thesis) found that a flexible rotation led to higher production per unit area than fixed 2 or 3 year rotations. The next step in this type of modelling is to assess the economics of the various rotations.

Innovative Acres data suggest that snow management increases soil water supplies by about 0.5 to 1.5 cm. If snow management were practiced on all land in the prairies that is cropped to cereals, the amount of water gained would be roughly equivalent to that now applied by irrigation. Snow management would also increase water use efficiency by agriculture through the reduction in summerfallow acreage (where most of the summer precipitation is lost as evaporation). Good management will be required to make the best use of the water gained by snow management.

Recommendations

1. Stubble sculpturing for snowtrapping is recommended for the Brown and Dark Brown soil zones. Further research is required on economical methods to better utilize snow water in the Black and Gray soil zones.
2. Investigations into ways to reduce the cost of chemical fallow in the Brown and Dark Brown soil zone are required.
3. The use of partial fallow systems in conjunction with winter wheat and/or other crops to reduce the length of the fallow period and increase soil protection requires further research.
4. Further research into the use of grain legumes in rotations as both cash and soil improving crops is required.
5. Further investigations into the economics of extended rotations through the use of computer modelling techniques which incorporate long term climatic data are required.



Y_c= 2142±713 KG/HA
Y_F= 2322±778 KG/HA
ΔY= 180±180 KG/HA
SOIL P = 17±11 KG/HA
FERT. P_2O_5 = 28±7 KG/HA
RAIN = 18±14 CM

Y_c= 1876±753 KG/HA
Y_F= 1955±763 KG/HA
ΔY= 79±258 KG/HA
SOIL P = 18±7KG/HA
FERT. P_2O_5= 30±9 KG/HA
RAIN = 17±8 CM

FIGURE 1. YIELD INCREASE TO SEED-PLACED PHOSPHORUS ON SPRING SEEDED WHEAT.

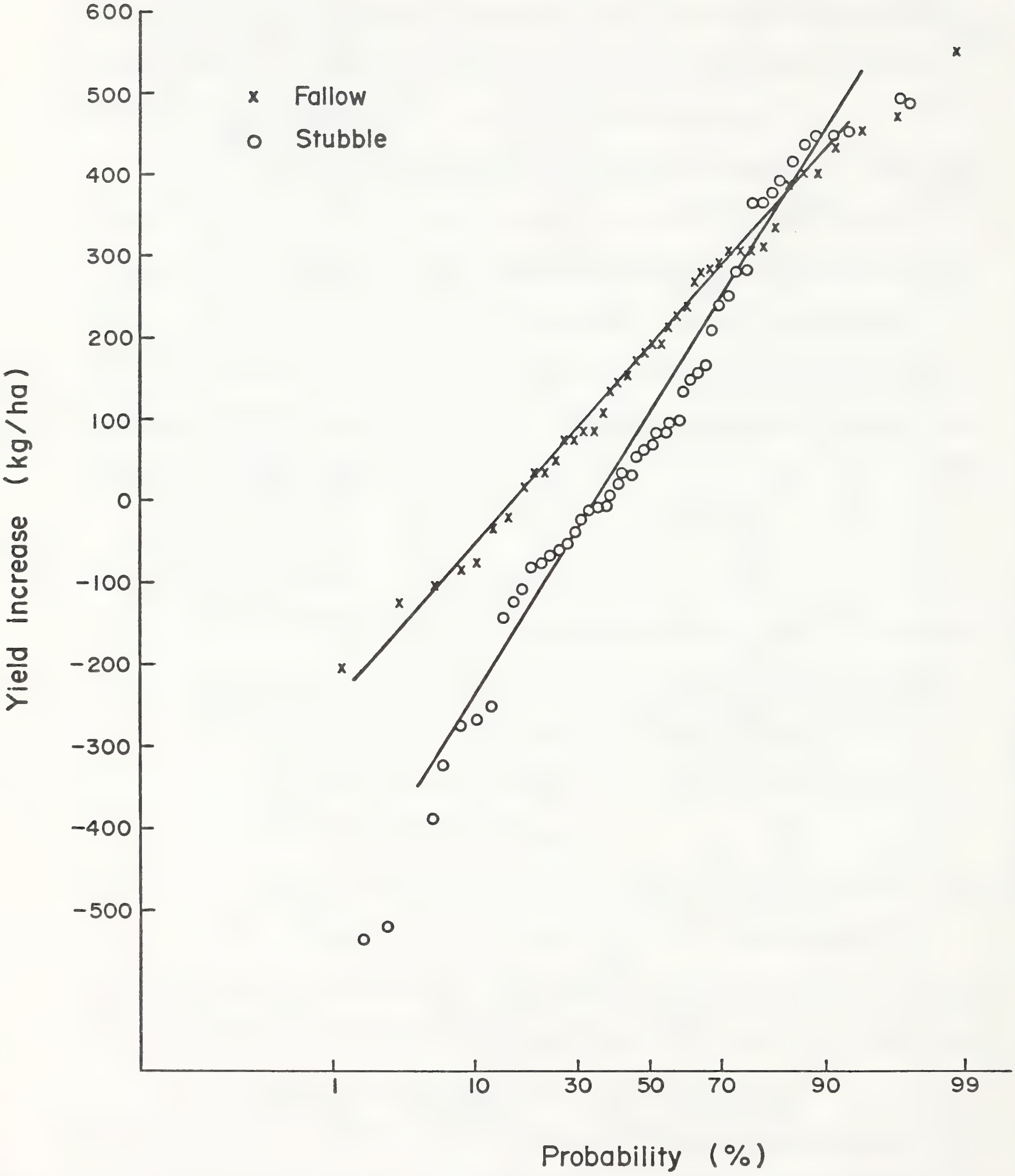


FIGURE 2. PROBABILITY OF A YIELD INCREASE TO SEED PLACED PHOSPHORUS ON SPRING WHEAT AND DURUM.

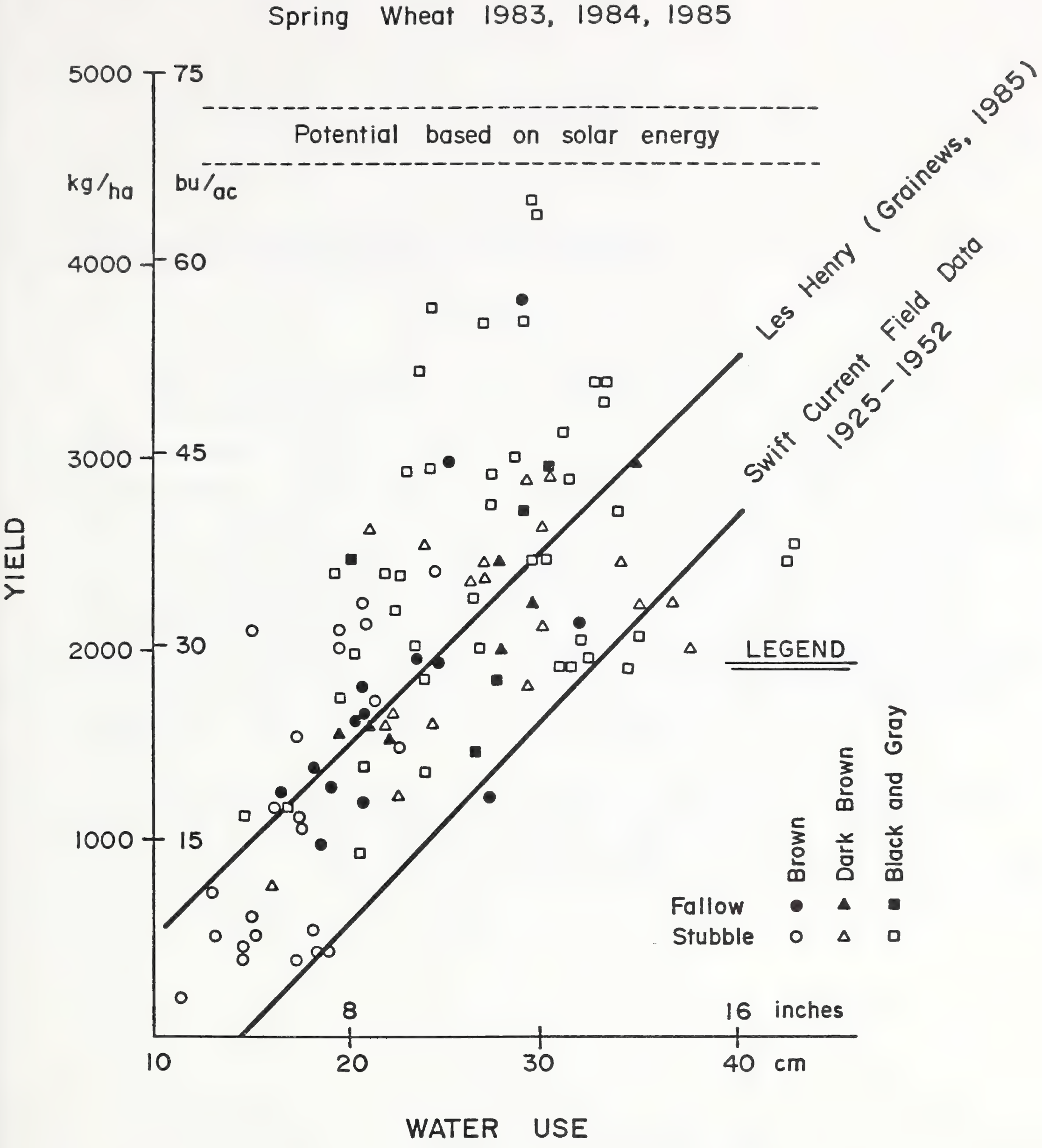


FIGURE 3. YIELD AND WATER USE ON INNOVATIVE ACRES FIELD.

ABSTRACT

Drought Management Roles of Government

The paper examines drought management roles in light of current and future issues facing the agricultural sector. These issues include: our ability to remain competitive with traditional competitors and future production from developing nations; addressing drought management issues during a period of declining real government expenditures; flexibility in research, technology, disaster relief and farm income management to meet possible violent swings in commodity supply or climatic factors; and the integration of environmental objectives into agricultural development.

The future strategic issues for government programming in the areas of technology development and dissemination, infrastructure, incentives, regulations and economic and income stabilization are discussed.

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1266E/k
September 15, 1986

Western Provinces Conference on the Rationalization
of Soil and Water Research and Management

"Moisture Management in Crop Production"

Marlborough Inn
Calgary, Alberta
November 18 - 20, 1986

MOISTURE MANAGEMENT - ROLES FOR FEDERAL GOVERNMENT

John Girt
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Agriculture Canada

October 1986

The views expressed in this paper are the author's and not necessarily those of the Federal Government.

The federal role in moisture management is an extremely limited one - farmers manage, not the government. What the government can do is to provide support to farmers and also monitor the effectiveness with which farmers are coping with the challenges of modern farming. The support that the government can offer covers a wide front. I have chosen to focus on the support that is or could be offered to assist producers deal with drought and soil and water management and, hopefully, come out ahead over the next decade or more. In other words, I wish to focus on the medium to long term. Since the availability and use of water on the farm is a function of soil as well as water management, I would like you to assume that except where the contrary is clear, moisture management includes all aspects of farm production affecting the supply of moisture, its retention and use in soils used in crop production, and forage but not other aspects of livestock production. As the water holding capacity of the soil is reduced by most types of soil degradation I have chosen to regard soil conservation as an integral part of sound moisture management.

Moisture management has to be addressed in the context that we expect for Prairie agriculture. Some relevant considerations affecting federal and other responsibilities are:-

1. Climatic change - recent trends in climate seem more and more unlikely to be a result of a stable climatic regime. Unfortunately, not only are we not sure of this, but of what the long run change might be. Greater variability may be the best assumption. Obviously this gives some pointers as to research priorities; it may also increase payoffs

from irrigation (other things being equal), and may severely stress crop insurance programs both in terms of financing them and their effectiveness in stabilizing net farmer returns.

2. Changes in international competition are having and will continue to have a substantial impact on Prairie agriculture. There have been substantial changes occurring in the way we view the world supply of food in making decisions affecting farm production. The key now is the ability to be competitive in the world market place, not necessarily to maximize the Canadian contribution to world food supply requirements. Not only do we face an over-supply in many commodities, but new competitors have recently emerged, many of whom have a substantive domestic market which affects their policies towards international markets. Many were until recently considered markets for Canadian grain products.

   Grain production in the EEC, China and India, to name three relatively new competitors on the international grain market, is based upon meeting domestic requirements with their governments covering the risks of domestic over-supply through export drives. The size of the domestic market provides both a market base and a revenue base for agricultural programs that Canada cannot compete with. In the case of the developing countries, the revenue base is more likely to be an internal pricing policy and foreign exchange policy keeping agricultural prices low on domestic and international markets. In the EEC, their policy supports agricultural production through high domestic consumer prices.

To Canada, however, the effects of both types of policy are the same. There is a greater domestic support base for international marketings in these densely populated countries than in Canada. The future long run competitive position of Canadian producers will rest on their ability to master the most productive techniques matched to the resource base, not so much on the ability to adjust to changing supply and demand situations. We must compete by lowering costs and pushing for fairer international trading arrangements. The federal responsibilities on the latter objective are well established and clear.

I will review the U.S. Farm Bill later in the paper but at this point, I would like to note that it is likely that in the medium term the U.S. dollar will fall in relation to other major currencies. Assuming that the Canadian dollar maintains its close relationship to the U.S., this will mean that Canadian competitiveness in grain production in future markets will be a function of the comparative advantage this country can command over the U.S. based on the natural resource base; capital, technology and managerial skills; and supply, transport and marketing system.

This, of course, only provides more justification for improved moisture management, but only if it improves net returns based on world market prices, not because it improves yields. Perhaps yields were an indicator of improved economic performance, but remember the spread between crop prices and prices for energy based inputs such as fertilizers were greater in the past than we can expect in the future.

3. The next issue to be addressed then becomes one of how to promote and support competitiveness, and improved moisture management in particular. Generally improvements in productivity in most industries, including agriculture, come about through human resource development - producers and individuals working in the inputs industry will make it work. I am not sure, however, that trends in the structure of both these sectors are presently favourable to the changes required to bring out gains in productivity. The inputs sector is becoming dominated by a few firms, using relatively limited product lines - not a good base for leading edge innovation.

   Generally, innovation comes from firms competing for specialized potential market niches, not for the control of large, e.g., North American, markets. However, as long as the same market forces are being felt by American as Canadian producers, continental market requirements may be sufficient to support the quite environmentally specific research and development that is required.

   Farms have become large and specialized with small profit margins and with increasing use of inputs (particularly fertilizers and pesticides). Innovation may be quite risky. However, I cannot find any financial indicators that Canadian producers have fallen behind in the technology race or been using inputs out of line with the net returns being received. This should not justify complacency. With low grain prices some cutbacks in inputs will be inevitable - a path the sector has not been forced down in recent memory. In other words, past performance may not necessarily indicate what the future outlook will be. Furthermore, we must qualify the recent level of performance, as potential returns have been lost as a result of non-adoption of moisture management practices (we do not even have a clear idea of what has been adopted). We expect that Prairie farms have lost the current equivalent of over $450 million annually through increased inputs and reduced yields from soil degradation alone (see Table 1). Drought costs for Manitoba have already been provided by Daryl Kraft. Investment in soil management should be driven by savings in these costs and other off-farm costs I will consider later.

4. The final issue is the need to address the appropriate allocation of government resources between short run aid and long term development of agriculture (see Table 2 for estimates of federal expenditures for Prairie agriculture). It is a difficult area, very much like the debate on allocations of funds for pure and applied research. To bluntly state the issue, it is one of determining with limited resources how much of government expenditures should go towards supporting the current structure for reasons of equity or welfare, and how much should be used to improve the economic productivity of the resource base and the human capital for the long term. The latter approach no matter what the immediate impact on the fiscal deficit will be, seems to be a real investment in the future.

   This is a key area for federal political leadership based on feedback from yourselves and the rest of the sector. In reality, of course, most programs do not belong completely to one of the alternatives mentioned. In the case of income support programs, it would seem important to continue to design packages that encourage appropriate adjustments to the long term needs for competitiveness in costs of production.

There is very little direct information available on what technologies producers are using to address soil management and other issues. There is a significant information void; however, I am not sure that this justifies more surveys and government data bases. It indicates the need to incorporate more data on production practices in existing surveys. I believe the real issue is the lack of sufficiently organized dialogue between all the players in the system. It implies more emphasis on the delivery of programs/information to farmers catering to their specific needs. Generally, here the federal government, if it becomes involved in farmer contact, works through agreements with the provinces who have the lead role in this area. Thus, we have seen the expansion of PFRA's Soil Conservation Service with advisory offices distributed throughout the Prairies under agreements with all the provinces. Federal agricultural research is also dispersed across the Prairies.

This emphasis on the grassroots as the basis of positive change also requires a well informed farm population. The federal government has been helping to make soil conservation, and through it moisture management, an issue by increasing communication/public awareness activities in this area. Last year's Agricultural Outlook Conference focussed on the issue; we are organizing annual National Soil Conservation Weeks; and we are preparing information bulletins and publications. Beginning next year it is proposed that National Soil Conservation Week be brought forward to mid-April.

Jointly, with the provinces, we are working on ways to improve the transfer of technologies from research to farms. ERDA subsidiary agreements that have been signed with Saskatchewan and Manitoba have included substantial programs to support the evaluation and demonstration of new production technologies in real farm situations (see Table 3). We have had preliminary discussions on similar agreements with Alberta. One issue that we jointly need to address is how to encourage the widespread adoption as opposed to development and assessment of appropriate technologies.

One way is to internalize both the costs of not adopting the technologies, and the benefits of adoption more completely in producer revenues and expenses. By this I mean that the price system would financially reward farmers for practising good soil management, and encourage those that do not adopt better practices more effectively than now. Such an approach, to avoid inconsistencies, would probably have to be dependent upon federal/provincial implementation agreements. They could include commitments to:-

1. Use cross-compliance requirements as in the U.S., as eligibility requirements for other programs. Cross-compliance would mean that eligibility for programs for some non-environmentally oriented objective, for example, farm credit, would be conditional upon the use of recommended environmental management practices, or upon the retirement of erosion prone land from crop production.

2. Use of financial incentives, or taxes, perhaps based on land zoning, for the adoption of recommended or unsatisfactory practices respectively. The incentives could be based on the costs the public incurs from unsatisfactory practices and the benefits it receives from recommended ones. Because of the nature of environmental issues it is extremely unlikely that all incentives and disincentives could be offered in a

national or even provincially consistent way. They would have to be targetted to specific combinations of environments and practices. Improved environmental management will require more regional sensitivity in program design and priority setting than either level of government has used to now. At the same time, policies such as pesticide regulations need to be reviewed and adjusted to make them more compatible wherever feasible with both their original objectives and sound soil and water management.

I must stress that I am putting these ideas forward as suggestions for ways to encourage the widespread adoption of improved soil management practices that will reap long term dividends both in terms of reducing the public costs of soil degradation and improving producer competitiveness for his and society's benefit. I firmly believe that the vast majority of producers, like the population in general, values these goals. We just have to examine how we can manage the economic system to achieve them and profit by their adoption. It is also interesting to note that the much maligned 1985 U.S. Farm Bill contains elements of the approach I am suggesting.

The conference organizers asked me to address the U.S. Farm Bill in the context of this Conference. To me there are two significant and interrelated aspects of the Bill. First, it represents an attempt to protect U.S. farm incomes in the short run by deficiency payments and export subsidies in such a way as to lead to declines in production in the medium term. The immediate effects are to increase the supply of U.S. products on the world market at a cost to the U.S. Treasury for wheat alone of over U.S. $2 per bushel of increased supply, in addition to U.S. $4-5 billion each year in deficiency payments for the remaining crop. Whether such payments are politically sustainable is a real issue. This aspect of the policy will hardly contribute to an immediate international or domestic rationalization of the supply situation. However, if the Bill is politically sustainable, it is designed to reduce crop production in the U.S. in the medium run. This, combined with a declining U.S. dollar, would result in an improvement in world commodity prices in dollar terms in the next decade. It is thus an attempt in the medium run to put right the supply surplus generated by the previous U.S. price support system.

Second, there is an attempt to coordinate the rationalization of the over-supply situation with a reduction in the public costs of soil degradation (estimated to be $2 billion annually) through an acreage reduction program for environmentally fragile land, the so-called conservation reserve. It is not clear how successful this aspect of the Bill will be in reducing the supply of surplus commodities, nor whether it will result in a permanent retirement of the most fragile lands. If it does achieve the latter, one may be tempted to argue that the signals that it provides are not consistent with those expected in a capitalist system - producers can be rewarded for doing the wrong thing. However, it is a deliberate approach to eliminate the public costs of soil degradation that should be watched closely even though a very expensive one (it seems that incentives of U.S. $45 - $90 per acre annually for ten years will be paid to participating producers). I would note, in passing, we do not have a complete estimate of the public costs of poor soil management in Canada. Recently my group has come up with a preliminary but crude annual estimate of $380 million for the direct off-farm costs of Prairie production practices.

Returning to the Prairie context, I would like to conclude by reviewing existing federal activities which have not yet been adequately covered. They span the more traditional areas of government involvement in soils management. I do not wish to downplay them; they will continue to be important in the future. The proposals that I have put before you would only increase their effectiveness.

In research (see Table 4) it is apparent that we must work towards a closer integration of natural resource issues and aspects of farm production. In governments and universities most scientists work on either crop production or research into trends in the quality and use of the resource base. Crop production scientists tend to work on maximizing physical production in relation to individual inputs. One challenge is to refocus the output of all types of crop production research so that it is designed to identify new technologies having an immediate and intended positive impact on improving revenues without increases in production costs and costs of environmental management or mismanagement. Much of the research on water in relation to agriculture that is not of a survey/monitoring nature tends to focus on the physical productivity of specific engineering options or broad cropping options and again is not oriented to providing directly revenue protecting or enhancing strategies for Prairie farms in a market context.

In assessing future priorities for public research one has to recognize the increasing role private research and development, particularly by the input companies, is playing. This makes public research management a more complex task. Allocations of federal resources amongst research programs have been generally in agreement with priorities identified by CASCC, federal/provincial committees and client groups. In the future, priorities will also be examined in the context of commodity and natural resource strategies that Agriculture Canada is developing in consultation with provincial governments and the private sector.

The federal government also provides a range of financial agricultural policies and programs that have a need perhaps to be examined from a drought or moisture management perspective. Is there a need to tailor its credit programs to yields as well as commodity prices so that required producer payments could be reduced in the years of drought? Already a federal/provincial committee has made some recommendations as to how to provide more producer protection in crop insurance schemes. A review of the federal tax policy is in process - now is the time to review existing relevant tax arrangements, e.g., the favourable treatment allowed farmers with taxable incomes for land clearing expenses (can we still justify this when marginal land is likely involved), or to suggest new possibilities to promote better use of what resources we have.

Finally we come to the controversial subject of irrigation. The report of the Pearse Inquiry into Federal Water Policy raised the issue of federal participation in irrigation development. Although the Inquiry almost recommended a federal withdrawal of support, recent decisions have confirmed continuing federal participation on the basis of it being cost-shared with the provinces. Additional criteria would be that it is expected to provide sufficient public and private returns to justify the costs involved (irrigation must be a profitable investment), the producers who could participate in irrigation must be supportive of it, and that there are no unacceptable environmental impacts. On the other hand, it must be realized that the potential schemes which meet these criteria only cover a very small proportion of the

Prairie agricultural land base, and irrigation will never be a panacea for the moisture deficit problems of most producers. It must also be recognized that some of the assessments of recent irrigation schemes are based on crop prices which, with the value of hindsight may have been quite optimistic.

Conclusion

I would like to end this presentation on a positive note. There are clear indications that medium run world market prospects are more favourable than current ones. World food demand will continue to grow and foreign exchange relationships are forecast to change favourably. There is a growing recognition of what being competitive in tomorrow's markets will mean, and a growing body of opinion that soil management practices should and can be improved.

Federal priorities, along with those of the other players, are consequently changing. The next decade will see an integration of agricultural development and environmental policy that will provide positive benefits to both sectors. Because of the very nature of environmental problems this will result in a greater regional sensitivity in programming, more federal/provincial coordination, and more emphasis in the design and delivery of public programs on inputs from farm organizations organized on an environmental, i.e., regional as well as commodity basis. I believe our discussions should be focussed on ways of facilitating this change ensemble rather than focussing on some of the actors, if we are to improve our efficiency and effectiveness in managing to stay ahead in tomorrow's economy and environment.

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TABLE 1

ESTIMATES OF THE IMPACT OF SOIL DEGRADATION ON FARM GROSS DOMESTIC PRODUCT (GDP)

($ Millions)

Region	Agriculture GDP - 1984	Estimated on-farm costs of soil degradation in 1984	Estimated percentage reduction in agricultural GDP attributable to soil degradation in 1984	Percentage of 1984 national degradation costs
British Columbia	583	22-25	4	3
Prairies	4,483	472-609	9-11	68
Ontario	2,689	140-193	5-7	20
Quebec	1,285	37-48	3-4	5
Atlantic	352	27-40	7-10	4
CANADA	9,752	698-915	7-9	100

TABLE 2

ESTIMATED FEDERAL EXPENDITURES FOR PRAIRIE AGRICULTURE
1983-1986

PROGRAM	PRAIRIES			CANADA		
	1983/84	1984/85	1985/86	1983/84	1984/85	1985/86
Agriculture Canada						
Agricultural Stabilization	6,612	23,255	17,996	9,691	83,609	30,904
Crop Insurance	108,573	134,079	159,640	133,963	190,167	204,762
Crop Drought Assistance	-	-	80,989	-	-	80,989
Research	53,082	60,820	58,985	213,175	248,216	246,149
Regulation Inspection	44,309	44,203	57,305	189,061	204,984	238,736
Canadian Grain Commission	13,897	14,693	14,555	6,968	37,538	38,305
Canadian Dairy Commission	48,806	38,924	38,522	347,576	332,489	301,000
TOTAL [1]	275,279	465,872	570,052	1,255,195	1,466,508	1,547,183
External Affairs						
WGSA	121,158	115,738	95,040	121,889	116,907	96,000
TOTAL [1]	142,067	128,328	161,707	510,053	410,916	511,101
Other Departments						
Transport	803,375	886,187	611,702	854,856	975,388	679,283
Regional Industrial Exp.	13,030	19,402	18,712	43,460	30,731	41,023
Science & Technology	12,870	31,730	17,355	31,972	54,147	40,126
TOTAL FEDERAL [1]	1,329,959	1,573,165	1,443,201	2,786,140	3,137,900	2,906,700

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[1] Includes programs and departments not listed.

[2] Preliminary tabulations - final data not yet available.

TABLE 3

ECONOMIC AND REGIONAL DEVELOPMENT AGREEMENTS

(SASKATCHEWAN AND MANITOBA ONLY)

ENHANCED SOIL AND WATER RESOURCE MANAGEMENT:-

- MONITORING EROSION
- SALINIZATION
- ACIDIFICATION
- PEATLAND - WATER LEVEL CONTROL
- DRAINAGE
- SHELTERBELTS
- WATER CONSERVATION
- IRRIGATION
- SOIL MANAGEMENT RESEARCH
- SOIL FERTILITY RESEARCH
- SOIL CONSERVATION
- SOIL CLASSIFICATION

FEDERAL FUNDING COMMITMENTS OVER 5-YEAR AGREEMENTS:-

- MANITOBA (1984-1989)	- $ 7,603,060
- SASKATCHEWAN (1984-1989)	- $ 17,642,000
TOTAL	- $ 25,245,060

TABLE 4

DROUGHT MANAGEMENT - ROLES FOR FEDERAL GOVERNMENT

RESEARCH BRANCH

Annual Soil and Water Expenditures for 1986/87 - $13 MILLION

42% ($5.5M) - Land Resource Inventory and Interpretation

35% ($4.5M) - Soil Management and Conservation

15% ($1.9M) - Water and Climate

7% ($0.9M) - Land Evaluation

A REVAMPED CONSERVATION DISTRICTS PROGRAM FOR MANITOBA:

A MEANS OF ADDRESSING DROUGHT AND OTHER LAND-USE PROBLEMS

Presented by

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At The
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A REVAMPED CONSERVATION DISTRICTS PROGRAM FOR MANITOBA: A MEANS OF ADDRESSING DROUGHT AND OTHER LAND-USE PROBLEMS

ABSTRACT

Manitoba has recently embarked on a new thrust program to more effectively deal with drought and other land, water and related resource management issues. The revamping of an established conservation district program to more effectively deal with land-use issues in the 1980's has been given priority. The primary focus of this new initiative is to use conservation districts as the mechanism for local decision-making, establishing program priorities and planning and implementing programs. Conservation Districts as incorporated bodies,are encouraged to adopt a more autonomous stance in the conduct of their affairs. A more client-consultant relationship and "business-like" attitude in their approach to working with government is preferred.

The Province has established a Manitoba Conservation Districts Authority to assist the Districts in acquiring the necessary planning, programming, financial and promotional services required to properly serve District programs.

Considerable interest has been shown by local landowners, farmers and elected officials in Manitoba's promotion of a "new deal" in soil conservation and management for the 1980's.

In addition to the five existing districts, five new districts have been targeted for 1990. As well, a long term management plan or scheme and a 5-year implementation program has been established as a primary objective for each district -- the management plan to be completed within 12 months of its undertaking. Progress to-date suggests that timing for the above target and objective is realistic.

INTRODUCTION

In the guise of addressing the subject of drought in Manitoba, the Western Provinces Conference presents an excellent opportunity for Manitoba to share with participants its recent initiative in dealing with soil conservation and the management of land and water and related resources. Manitoba has recognized the need for some integrating mechanism to deal with land-use for some time. A variety of Acts have been passed in an attempt to provide a legislative mandate for dealing with this rather complex undertaking. Resource management districts, drainage districts and other such mechanisms have been enacted to deal with this matter. The most recent attempt of this nature was the approval by the Province of the Conservation Districts Act in 1976.

The recent "crisis" tag assigned to soil conservation as a result of the work of federal and provincial agencies has helped focus local attention to this area of concern. This, coupled with a new environmental awareness in the 1980's provides an opportune time to recognize soil and water management as a high priority program and new thrust for Manitoba. The "Soil at Risk" findings by the Senate Committee serve to underscore the importance of a new approach to soil conservation.

THE CONSERVATION DISTRICTS PROGRAM

The objectives of the program are intended to serve three purposes.

1. To have decision-making and priority setting for land and water management occur at local levels within overall policy guidance.
2. To ensure that local decision-making bodies have the professional, technical and financial resources to properly address their mandate.
3. To bring a better understanding and appreciation of the need for an integrated approach to land management by a program of participation and education at the local level.

The basic premise for the above is that better land-use practises are most likely to occur through the cooperation, participation and will of local landowners and communities. The Conservation Districts program in Manitoba is being revamped to provide a mechanism to achieve this end.

ORGANIZATION

Without going into detail, the organization of the Conservation Districts can be briefly described as follows.

Conservation Districts constitute the most important component of the program. A District is structured under the Conservation District Act as a legally constituted corporate body responsible to the Minister for Natural Resources.

Each District is comprised of a District Board and a small office staff, usually a District Manager and clerk/secretary. The District Board is appointed from Sub-District Committees that represent the geographic entities comprising the District. The District boundary may include municipalities, portions of municipalities and/or watershed boundaries. The District is funded on a 75% Provincial/25% Municipal basis.

A seven member Conservation District Commission representing provincial land-use agencies, Conservation Districts and the Union of Manitoba Municipalities is responsible to the Minister for overseeing program submissions from the Districts and recommending approval of programs and policies. The Commission reviews provincial grants to the Conservation Districts and makes recommendations to the Minister regarding District funding.

A Conservation Districts Authority has recently been established with a mandate to provide professional, technical, financial, and program promotional and education services to the District Boards. Authority staff, eight in number, also serve a Secretariat function to the Commission. The role of Authority staff is to ensure that services are provided to the District. Such services can be made available from government agencies, consultants and/or other non-government organizations. The primary function of the Authority, therefore, is to locate and coordinate the delivery of professional and technical assistance to the Districts.

THE ACT

The Conservation District Act represents the outcome of several years experimentation; many of which were characterized by tension, strife and lack of acceptance. Drainage districts provided for in the 1930's were followed by an attempt to integrate land and water management through the Watershed Conservation District Act in 1959. The Resource Conservation District Act provided an even broader mandate to include other land and water related resources; fisheries, wildlife, forestry, etc.

Even today, the Act receives criticism because of its ambiguity related to other provincial jurisdictions. The very nature of the words describing its mandate e.g. land-use management, soil conservation, resource conservation begs conflicts and contradiction of resource interests. For example, Manitoba's Provincial Planning Act and Conservation District Act are often questioned in terms of their compatability.

The Conservation District Act begs review and updating. However, at this time it is intended that a motto of "let the deed show" be pursued in revamping the program. A revised Act based on tried and proven endeavours would be preferred to an Act revised on the basis of hindsight and speculation.

Perhaps two key aspects of the present Act most deserving of attention and revision are:

- a de-emphasizing of engineering interests as these relate to water management and drainage;
- a refocussing of attention from water to land management and, hence, a de-emphasis on the significance of watershed boundaries.

THE MANAGEMENT PLAN (SCHEME)

The Act makes reference to a "scheme" described as "a program developed by or for a district in accordance with the purposes of the Act". Under the Act, a scheme is to be developed by the District Board within two years of establishing the District. It is interesting to note that none of the five Districts in Manitoba have yet adopted a scheme. Attempts to-date have resulted primarily in resource inventories.

The Act defines the mandate of the District Board as including but not limited to drainage improvement, development and maintenance; flood control and soil conservation; water conservation, recreation development, forestry, wildlife, fisheries and other programs of resource conservation and development the Board may deem necessary or desirable. Hence, one can readily appreciate the opportunity for jurisdictional conflicts and the need to develop some working framework which provides for the integration of these resource interests.

PROGRESS

Considerable progress has been made since 1985 in revamping the Conservation Districts program. This program reorientation and attention has been particularly timely because of the "crisis atmosphere" that presently prevails in terms of agriculture and soil conservation, and, the new public awareness and concern for environmental quality and heritage conservation.

The first significant contribution to a change in the program occurred in 1985 when Manitoba established staff specifically assigned the task of providing program support to the District Boards and the Commission. Prior to this, Departmental staff members were designated as District Coordinators to, in addition to serving other duties as full-time civil servants, be responsible for program planning, research and implementation on behalf of the District. The Authority office has an Executive Director, three planners, two financial officers, an extension specialist and a general manager. Preference has been given to acquiring staff with a general background in regional planning or related interests.

The Conservation Districts program has been given its own identity. Prior to this time, the program has generally been (and perhaps still is in some quarters) perceived externally as a drainage program headed by the Provincial Water Resources Branch. Internally, by Agriculture, as a program that inadvertently wound up in the hands of engineers, and, by Municipal Affairs staff as a program that should be encompassed by the Planning Act and delivered by existing municipal services. Recently, Departmental initiative has promoted a discrete identity by establishing the Conservation Districts Authority as a separate entity within the Department and having this new agency report to the Deputy Minister. The support staff of the Authority now serves as a focus for the Districts and the Commission in their land and water dealings.

A major effort was made during the past year to establish and maintain a perception of District Board autonomy. It is imperative that District Boards recognize the autonomous nature of their corporate status; that they insist upon an arms length operation from government, and, that they understand their responsibility for program development and implementation. To assist in this regard, financial control, program planning and implementation is now being transferred to the Districts as part of their increased responsibility.

District Boards and others have agreed that a District Manager and secretary are a minimum staff complement when a Conservation District is to be formed. In fact, the ability of provincial and municipal interests to fund a District Manager's office is one of the factors dictating the size of a District. All Districts in Manitoba are now staffed with District Managers.

In past, District Boards have depended on services being identified, planned, programmed and delivered by government agencies. By resolution, Boards forward some vague description of their requirements to these agencies. The Districts have often expressed dissatisfaction with the nature of work performed or delays in program delivery. Considerable progress has been made in assisting the Board in planning and programming its own affairs and in seeking commitments from various agencies to a program delivery schedule. Every effort is being made to establish a "client-consultant relationship" between the Boards and government services, and, a more "business-like" approach to the conduct of their affairs.

The preparation of a management plan, about a 12 month process, is well advanced in one District. Planning procedures are underway for the development of a management plan in a second District. A consultant will be engaged to initiate the management planning process in a third District.

Numerous meetings have been held with local landowners and elected officials. Considerable interest has been generated by the "new deal" for Conservation Districts in 1986. This new initiative has been presented to more than 500 municipal councillors. A very positive response has been identified with particular reference to the following key points of interest

- local decision-making;

- local autonomy in the conduct of affairs;
- local control over finances;
- local responsibility for overseeing program implementation;
- Conservation Districts as a "one window" approach to doing business with government;
- structuring a Conservation District specifically suited to local needs and concerns;
- Conservation Districts are viewed as a conduit for the flow of provincial, and federal dollars and other sources of funding specifically designated for local land-use improvements and resource developments.

The formation of a new district (District #6) is anticipated on or before next Spring. The seventh District is hoped to be incorporated by the Fall of next year, and, at least one additional district may be in place before March, 1988.

TARGETS

In a recent submission to the Management Committee for the Canada-Manitoba Agri-Food Development Agreement, the Conservation District Authority identified two specific targets:

1. to establish five new Conservation Districts by 1990;
2. to prepare management plans for the five existing districts: each plan to be completed within a 12 month period.

SUMMARY

Manitoba has made considerable progress this year in alerting municipal interests and landowners to a "new deal" in Conservation Districts. Although wary, local elected officials and landowners have shown interest in this provincial initiative. A vision of local autonomy, local decision-making, control of local expenditures, a one window approach to a myriad of government interests, and, a possible conduit to other sources of funding for local land and water management initiatives has prompted new attention to the Provincial Conservation Districts Program. Targets established for the Conservation Districts Program appear realistic at this time. The key to success is primarily dependent on (1) a better understanding by all parties as to what constitutes a "conservation" district or "land/water management" program; and (2) the Districts' roles and responsibilities in developing a long-term vision for the future and five year projections for implementing programs; (3) financial support from all levels of government; (4) opportunities for associations, non-government agencies and communities to actively participate; and (5) a willingness of landowners to take a long-term view in very tough times. It will take time but the time is ripe for such an undertaking.

LOCAL GOVERNMENT'S INVOLVEMENT
IN
SOIL CONSERVATION IN ALBERTA

PRESENTED BY

ROELOF HEINEN

AGRICULTURAL SERVICE BOARD CHAIRMAN

and

COUNTY COUNCILLOR

COUNTY OF LETHBRIDGE NO. 26

The first Agricultural Service Board was formed in Alberta in the late 1940's with the intent to initiate a Weed Control Program for the purpose of controlling the ever increasing infestation of weeds on agricultural lands. The Province of Alberta has 68 active Agricultural Service Boards in Counties, Municipal Districts, Special Areas and Improvement Districts, which is unique to Alberta.

Boards consist of elected municipal councillors in Counties. In Municipal Districts, they consist of one or two members of Council; one or two ratepayers; and an officer of the Department of Agriculture - usually the District Agriculturalist. These Boards operate in accordance with Provincial Government Regulations under the Agricultural Service Board Act, and are an advisory body to assist the Council and Minister of Agriculture in matters of mutual concern They advise on the organizing and directing of programs under such Acts as Weed Control, Soil Conservation, Agricultural Pests, Agricultural Chemicals and Livestock Diseases. These Boards assist in proper land utilization with a view to improving the economic welfare of the farmer, and also promote and develop agricultural policies to meet the needs of the municipality.

Acting in the capacity of Service Board Chairman for the past six years, I have observed many changes to our agricultural programs, and feel we are one of the more advanced Boards in the Province.

Agricultural Service Boards employ a full-time Agricultural Fieldman who acts as an administrative officer carrying out the duties and powers of the municipality under all Acts relating to agriculture. These Boards conduct regular meetings where the findings of the Fieldman are formally presented.

Ideally, the Agricultural Fieldman initiates and oversees crop protection programs with very little political interference. This includes issuing Weed and Soil Conservation Notices, and following up on these notices to ascertain compliance or non-compliance of the Acts, and whether corrective measures are required. At times, a fine line must be drawn between what constitutes a weed or soil erosion problem and what the general public perceives to be a problem e.g. to allow Kochia to grow in a saline area which absorbs the excess moisture; or a fall flush of weeds on summerfallow, to retain a trash cover on the soil.

Weather plays a substantial role in the management practices a farmer utilizes to ensure crop production. In extremely dry years, such as 1984 and 1985, money expended on chemical purchases decreased and weed and soil problems tended to increase. To counteract this, the owner will cultivate his fields more frequently than during a normal year as he weighs the cost of diesel fuel compared to chemical. The equipment costs per hour for cultivating a particular field is not readily identified as a direct expense. Very seldom is soil conservation a problem when a farm is well managed.

During the 1930's, soil erosion threatened the very existence of farming as we know it today in Western Canada. Since that time we have adjusted sufficiently and have developed programs and farming practices to minimize soil degradation.

In severe cases a Soil Conservation Officer is required to issue a notice. When the date to complete the action stipulated in the notice has expired, and the owner is negligent and has not launched an appeal, remedial work can commence. Charges for this type of action such as cutting ditches or ripping frozen lumps to the surface with heavy equipment are charged to the owner and collected as a tax against the property. In certain instances, farmers can access funds through the Provincial Soil Conservation Area Program (S.C.A.P.) whereby 60 percent of the costs are borne by the Province, and 40 percent by the farmer. S.C.A.P. projects are administered through A.S.B.'s.

Under the Agricultural Service Board Act, when it is determined through investigation and inquiry, that wind or water erosion has impoverished or is in the process of impoverishing the land, the Board or its agent shall report its findings to the Council or Minister of Municipal Affairs. The Council then sets a hearing date at which all persons having an interest in the land may appear to defend their actions or concerns. Upon receipt of the Board's report, the Council may declare the land referred to in the report to be subject to supervision or reclamation. When taken under supervision the Agricultural Fieldman and District Agriculturist shall consult with the owner, and mutually work out a plan for proper farming practices which the owner shall undertake to restore productivity to the land. If Council is of the opinion that supervision of the land would be ineffective, it may recommend in writing, that control of the land be taken from the owner and that an Order of Reclamation be issued. The Council would then pass a by-law for this purpose.

Revenue received from lands rented for reclamation is applied firstly, to any expenses the municipality incur, and secondly. to any taxes owing on the land. Surplus funds are returned to the owner. This action would only be utilized in extreme cases, and is more practical where serious weed problems exist rather than for soil erosion problems. Past history has indicated that owners who previously experienced soil erosion make better managerial decisions the following year, which results in better farming practices.

Because we have a grassroots involvement with the farming community and can respond to the farmers' needs almost immediately, Service Boards should remain a function of local government.

In conclusion, I would recommend the following to improve conservation farming practices:

1. Agricultural Service Boards cooperate with Alberta Agriculture to retain Soil Conservation as the No. 1 priority. Senior Governments should exercise their powers on Boards who are reluctant to enforce Provincial Regulations.

2. More emphasis be placed on educating both the general public and new farmers in the area of Soil Conservation, to ensure the longevity and productivity of the soil. Future generations are depending on this.

3. Conferences such as this, should continue, so that a flow of ideas can be exchanged which will benefit agricultural production in general.

PLENARY SESSION III (CONTINUED)

CHAIRMAN, R. T. ADAM, DIRECTOR, ALBERTA AFFAIRS,
PRAIRIE FARM REHABILITATION ADMINISTRATION,
EDMONTON, ALBERTA

AGRICULTURE INDUSTRY'S PERSPECTIVE
OF
MANAGING DROUGHT

BY: Richard Albutt &
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ABSTRACT

Over the past few years, inspite of the downturn in the farm economy, the market for conservation-type implements has remained fairly buoyant while many other sectors of the industry have declined significantly. Farmers are becoming more aware of the benefits of conservation farming and moisture management and are tailoring any new purchases in that direction. The future looks more promising for businesses able to stay abreast of the latest in conservation tillage technology.

Although some conservation tillage tools like the blade cultivator and the rodweeder have been around for many years and are still effective for conserving moisture and soil, other implements to complete the system are somewhat lacking. Devices in the area of trash management like straw choppers/spreaders and rotating harrows are relatively new and still need to be refined. Seed drills are undergoing major changes to improve trash clearance and to more effectively place both seed and fertilizer. These previous innovations are discussed in this paper along with an industry outlook on future developments in conservation farming equipment.

In many cases the economic difficulties that farmers are faced with will dictate the necessary changes in farming practices. Its fortunate that the future direction of conservation farming fits well with the farmers need to increase yield and/or reduce the time and resources to produce a crop. Things like more efficient weed control, fewer operations to produce an adequate seedbed, implements requiring less energy, more efficient use of fertilizer and minimal capital expenditure all imply conservation and provide the basic guidelines for implement development in future.

AGRICULTURAL INDUSTRY'S PERSPECTIVE ON DROUGHT MANAGEMENT

Richard M. Albutt and Simon A. Hann
Versatile-Noble Cultivators Company

Introduction

Manufacturers of farm equipment are currently caught in the same poor economic conditions that are affecting farmers. Although moisture management and the interrelated problems of soil degradation are a long term global problem for researchers, governments and philosophers, the short term problems may influence the long term picture.

In this geographic area the drought of 1984 and 1985 has brought much attention to the need to make best use of available moisture, and on a national level there is now a greater awareness of the problems of soil erosion. Senator Sparrow's report entitled "Soil at Risk" has gone a long way to bring this issue to public attention.

During the reduction of farm equipment sales over the last five years, the farm equipment manufacturing industry has undergone some of the most significant restructuring in its history. This has occurred primarily with the major companies; most of the "short-line" companies are attempting to hold on, and wait for a "turnaround" in the economy.

Short-line manufacturers with local market areas traditionally have developed specialized equipment suited to those local areas. Many of these companies are heeding the call to conservation tillage and moisture retention and are spending their development budgets, even though they have been reduced, on conservation tillage equipment. Even the brochures and literature of the major companies emphasize the conservation tillage aspects of their existing equipment most than they did just a few ago.

From a manufacturer's perspective, competition in conservation tillage and seeding equipment has increased significantly and it will continue to increase.

A 1985 survey brought to our attention by the Prairie Implement Manufacturers Association showed that in 1981 there were 29 models of heavy duty, high clearance minimum/no till seed drills in the marketplace and by 1985 there were 99.

This competition, which has occurred during a time of declining unit sales, has compounded manufacturers financial problems and reduced the amount that each company is able to spend on bringing new equipment to the marketplace.

If the current economic conditions, i.e., commodity prices, stay depressed for much longer than consolidation will take place among the "short-line" manufacturers and could in the long term reduce the amount of specialized equipment in the marketplace to suit the varying conditions in different areas.

On-farm demonstrations and test plots are crucial to the transfer of research and new technology from the research stage to actual use on farms. Farmers have different conditions and needs; before they invest in new ideas, understandably, they want to know what they will work on their farm.

Farm implements are difficult to transport and demonstrate; programs and organizations as as Farming for the Future, Prairie Farm Rehabilitation Administration and conservation tillage groups play an important role in this respect; and of course, the Federal Agricultural Research Stations are prime movers in developing new techniques; their current level of cooperation with manufacturers is encouraging and should be expanded.

In summary, manufacturers view conservation tillage and moisture management as areas for development in the future, the rate at which new and better equipment will enter the marketplace will depend on the ability of farmers to make a profit and invest in new equipment, and thus give manufacturers confidence to spend money on developing the equipment to do the job effectively.

Potential for Future Equipment Development

Soil degradation due to drought conditions is almost as bad in the 80's as it was in the 30's. Erosion is as noticeable today as it was back then. Climatic conditions are similar but you would think our farming practices would be significantly improved to cope with these conditions. After all, there were several significant innovations in tillage equipment that evolved since the 1930's to lessen the impact that drought was having on crop production. These innovations such as the blade cultivator, rod weeder and heavy duty chisel plow are available to today's farmers yet the problem still persists. It is evident that eight the machinery and systems available are not quite satisfying the needs of all producers or they have not yet been convinced that it will benefit their operation. Meetings such as this certainly help to educate users and promote the concepts, but there is still a lot that can be done to enhance the overall performance of conservation farming equipment to make it more appealing to the majority.

I wish to review with you the various operations within conservation farming; what the objectives are for each operation; what equipment is available to do the job today and what produce improvements are required to do a better job in future.

Harvesting

A good conservation farming systems starts with harvest. The most desirable situation is to have surface straw and chaff as uniformly distributed after harvest as it was before. This not only facilitates subsequent tillage, spraying, or seeding operations, but also provides the optimum in terms of uniform soil and moisture conservation.

Unfortunately, swathing has become a necessary evil throughout most of the prairie provinces. Once 20 to 40 feet of crop has been funnelled into the combine it is difficult to get is spread back out again. There are several straw choppers and spreaders on the market that are doing a pretty fair job.

The optimum however, would be to advance to direct cut headers where all the threshing and separating is done along the full width of the header. The crop comes in the front of the header and trash is ejected straight out the back. Only the clean grain would be conveyed laterally to a central hopper. This would ensure the most uniform distribution of straw and chaff on the field after harvest. I am sure somebody in the industry is toying with this concept.

Primary Tillage

Once the crop is harvested the next operation under a minimum tillage program is either a herbicide application or some form of primary tillage. Any tillage in the fall should leave as much stubble standing as possible to trap snow so there is a uniform infiltration of moisture over the whole field in the spring. The tillage operation should be aggressive enough however, to kill any weeds growing the stubble and fracture the soil sufficiently to allow moisture infiltration and prevent runoff through fall, winter and spring. The heaviest concentrations of trash will be encountered in the fall so the tillage equipment used should have ample clearance to prevent bunching or plugging of straw. In some cases it may also be necessary for this primary tillage tool to inject fertilizer and/or incorporate herbicide.

From a stubble retention point of view the most popular primary tillage tools are the wide blade cultivator and chisel plow. The blade cultivator was developed primarily to conserve surface residue. It retains the most trash (90 to 95% per cultivation) of any tillage tool currently on the market. It is the optimum in terms of soil and moisture conservation but is sometimes criticized for not preforming well at shallow depths and not killing shallow rooted weeds. The chisel plow on the other hand does a good job of killing weeds but does not retain as much surface residue (80 to 90%) and without harrows will leave the field fairly rough allowing it to dry out quicker.

We at Versatile Noble are seriously looking at a compromise between the blade and chisel plow - a tillage tool that will work shallower than a wide blade and retain more surface residue than a chisel plow. In our field comparisons to date we have also found this new blade-type cultivator pulls 10 to 20% lighter than a conventional chisel plow and somewhat lighter than a wide blade. It is designed with less lift than a wide blade allowing it to work shallower and/or at higher speeds without excessive soil disturbance. It covers the same width as three conventional 16 inch sweeps so there are one third as many shanks going through the ground burying less straw. We expect this machine will satisfy the requirements of a larger percentage of the conservation-minded farmers.

Periodic deep tillage (once every 4 to 5 years) is getting some acceptance from minimum and zero-tillage farmers as a means of improving moisture infiltration particularly when shallow hard pan forms as a result of continuous tillage or in soil types with low organic matter that do not permit the free movement of water. Some equipment is adaptable to deep ripping, others are designed specifically for that purpose. Caution should be exercised however, with respect to deep tillage in certain soil types and during drought conditions. Moisture evaporates more quickly from these deep fractures in the soil compared to leaving the soil undisturbed, and the crop is apt to suffer rather than benefit from the operation.

The University of Nebraska is experimenting with subsurface tillage using a modified wide sweep. Tines protruding from the bottom of the sweep break up hard tillage planes to facilitate root growth yet the sweep system maintains the benefits of residue on the surface. This appears to be a feature worth considering in future development of blade-type cultivators.

Seedbed Preparation

Tillage, if necessary, immediately prior to seeding should be kept to a minimum. It has been found that with each conventional cultivation stroke you lose an average of 5-10 mm of moisture.

The objective in this operation is to eradicate any weed growth prior to seeding, firm up a seedbed and seal the soil surface to reduce evaporation. And in the interest of conservation the above is accomplished while at the same time as much surface residue is left uniformly distributed as possible.

One of the optimum tools for this operation has been the rodweeder. This machine does a good job of working shallow to kill young weeds and firms and levels the ground prior to seeding. It will also work under surface residue with minimal incorporation. Getting the machine to work in firmer ground and to stand up in rocky conditions requires a more durable design. Morris have a new model out now that can handle the more difficult conditions and Edward's also make a fairly durable machine.

The other option to rodweeding is a shallow cultivation followed by harrows and sometimes packers. Although this system buries more residue it is an accepted practise especially when incorporating herbicide.

Future tillage implements should be designed to work shallower and with more consistency in terms of depth control to better control weeds without drying out the soil and without incorporating too much surface residue. Consistent depth control or contour following capability is essential to guarantee a uniform seed bed. This can be achieved with narrower section widths and more flexibility front to back. Designing a tillage tool to retain surface residue and at the same time effectively kill weeds is a real challenge. You usually have no problem accomplishing both under dry conditions. When it is wet, however, secondary tillage attachments have been required to help eradicate weeds. Stubble treaders work effectively without destroying surface residue. Tine harrows have also been used but do not function well in heavy trash. To get the job done without requiring costly attachments would require some basic changes in sweep design; perhaps a variable pitch to achieve more or less soil disturbance depending on soil moisture. Such a system is worthy of further investigation.

The requirements of tillage tools for summerfallow operations are similar to those for seedbed preparation except the stubble retention aspect is more critical. There should be sufficient residue (1500 kg/ha on sandy soils and 1000 kg/ha on clay soils) left on the soil for up to 20 months to protect it from erosion and seal in moisture. Blade cultivators and rodweeders usually have no problem satisfying this requirement (repeated use of a rodweeder however, will pulverize the top layer of soil).

Seeding

Seed drill development offers the most opportunity for improvement in conservation farming. The goal for many drill/seeder manufacturers is to combine as many operations as possible with seeding. In striving to reach the ultimate in minimum or no-till seeding, some companies are trying to adapt primary tillage devices for seeding (i.e., the air seeder units); while other companies are trying to adapt seed drills for working into primary tillage (i.e., the heavy no-till drill units).

Several drills are now available which can place all the fertilizer requirements for the crop either beside or below the seed where the least amount of fertilizer will do the most good. Applying fertilizer in a separate operation either in the fall or prior to seeding is no longer acceptable especially for no-till. Air seeders are now able to distribute fertilizer and seed in two air streams so they can be separately placed in the soil at the time of seeding. designs to below or side band fertilizer when seeding are going through several changes now to achieve the optimum placement with the minimum soil disturbance. Morris is working on a new shovel for their air seeder. Haybuster and ourselves are also refining opener design for banding drills.

Improving trash clearance with hoe and shovel type seeders is a high priority to handle the heavy trash conditions encountered in minimum or no-till seeding. Vertical and lateral clearances under the machine are being improved as is the shank profile to optimize soil and straw flow around the openers. Cutting coulters are being tried as a means of clearing more straw. They seem to be best suited to no till where they have firm soil to cut on. Under minimum tillage they do not always cut the straw and can add to the plugging problem. There are numerous other systems being tried to help clear straw - too many to mention at this time and none that have proven to be practically and economically feasible.

Disc type openers are gaining acceptance for seeding under conservation tillage mainly because of trash clearance and minimum soil disturbance. They require considerable weight and a durable rock trip to perform well under some of the adverse conditions. To date the banding of fertilizer with these units has only been achieved with separate openers placing fertilizer beside and somewhat lower than the seed. We are Versatile Noble are looking at various practical ways of separately placing both seed and fertilizer with one disc-type opener.

Below banding of fertilizer by mechanical means usually requires more machine weight for penetration and more energy to pull the machine at a deeper depth. To achieve the same results with less wear and tear on the machinery, Agriculture Canada and ourselves under a Farming for the Future contract have been looking at high pressure liquid fertilizer injection as one solution. Deep placement of fertilizer using high pressure injection does not require as much energy as pulling a tine through the soil at that depth. Some logistical problems related to the volume of liquid required, and the pumping systems need to be resolved before this concept can advance much further.

The environment created in the soil for the seed to grow in is another important consideration in future seeder development. More consistent depth control is one area requiring major improvement. Methods of coupling the opener to its respective press-wheel or gauge wheel are being looked at; as are devices for controlling seed bounce particularly when using air seeders. The furrow formed by press wheels should seal in moisture without excessive compaction over the seed and serve both as protection for the seedling from wind and a funnel to direct moisture to the root zone. The ideal situation that drill manufacturers are striving for is to have all the seeds placed at exactly the same depth below the bottom of the furrow preferably in moist soil and the fertilizer in a separate band below and/or to the side of the seed. Practically speaking, however, placing the seeds within 6 to 8 mm of the desired depth is more realistic without increasing the cost of equipment significantly. Under drought conditions, it is more critical that the seed simply be placed down into moist soil rather than all at exactly the same depth.

There is some interesting work being done in the area of moisturizing seed prior to planting. This technology may help to minimize the risks of seeding in drought conditions. The crop can be established quicker and will better utilize spring moisture lessening the effect of a hot dry summer. If the concept works well and consistently boost yields, there would be an instant market for on-farm seed moisturizers particularly in dryland areas.

Herbicide Application

There are numerous systems for chemically controlling weeds - from pre-emergent to post-emergent applications and liquid or granular forms of chemicals. From a conservation point of view, the systems being promoted are those that involve the least amount of tillage and are not hindered by a good trash cover on the soil. This implies incorporation with minimal disturbance to the surface residue (i.e., subsurface application); or pre-emergent chemicals that don't require incorporation but don't get tied up on surface residue; or effective post-emergent chemicals.

Since herbicide can be one of the highest input costs on the farm, the application equipment must be fairly precise to minimize waste. Equipment to incorporate chemical must work to a uniform depth and provide 100% coverage to give the best results. A wide blade cultivator with herbicide distributed beneath the blade has potential for providing a sheet of chemical at one depth without disturbing the surface residue. Both chemical and moisture remain sealed in. Herbicide applicators for granular and liquid chemical are undergoing continual development to improve metering and distribution to minimize rates of application without sacrificing effectiveness. The only way to encourage more chemical weed control rather than tillage and offset the high cost of chemical is to reduce the rate and cost of application. More precise low volume sprayer nozzles; shields to prevent wind drift; and chemical injection systems to facilitate switch and blending chemicals are all being developed to make more effective use of herbicides. Development of good herbicide applicators is becoming more and more critical as farmers shift toward minimum and no-till farming to conserve moisture, fuel, soil and money.

Conclusions

The battle to conserve moisture for crop protection in drought stricken areas is being fought on several fronts - harvesting, tillage, seeding and herbicide application. The market for suitable equipment for any or all of these operations appears lucrative. Acreages under conservation are still growing at an encouraging rate so the demand for equipment will continue to be strong. To meet the inherent needs of conservation equipment will require more innovative product design; close consultation with research groups exploring new frontiers in conservation; and frequent monitoring of farmers using the latest equipment for their input into future designs.

Recommendations

We, in industry, feel the following will further the cause of conservation farming practises in western Canada:

1. Government agencies like PFRA should continue and even expand their conservation demonstration programs and make every effort to use locally manufactured equipment whenever possible.

2. Just as provincial governments provide an agricultural extension service for farmers the federal or provincial governments should provide an agricultural service for industry to keep industry abreast of research in the area of conservation among other things.

AN ALBERTA PRODUCER'S EXPERIENCE IN DROUGHT MANAGEMENT

by

NORMAN STORCH

Our farm is located at the northern edge of Special Area II, about 25 miles north of Hanna. I grew up in this general area. When I got married in 1973 there was no room for me on the family farm so my wife, Leona, and I ventured into the poultry business. We bought 40 acres and built a Broiler Hatching Egg operation with a quota of 6,400 layers.

Those of you who know this area of the province will already be aware that I do not follow the norm; because this is grain and cattle country. I don't think there is a chicken joke I haven't heard but that is alright the chickens have saved my bacon more than once.

In 1976 we expanded into grain and cattle, which brings us to the present. We currently farm 1,600 acres with 1,400 acres under cultivation, the remainder in grass, both tame and native. We also keep 65 cows.

Average annual precipitation for our area is about 15" with probably 6" to 9" of rain in the growing season. The soil type for the area is dark brown. The texture varies all the way from very erodable sand to heavier clay soils which are usually solonetzic and generally slightly acid. Salinization is at present not a major problem on our farm. We soil test for fertilizer requirements, use good seed, and spray with the best herbicides available. We try to do a job and farm for a bumper crop every year.

Now having told you all this we'll get on to the topic. "Drought Management". In preparing this presentation two words continually crossed my mind. They were "confidence" and "flexibility". I would like you to keep those two words in mind for the next few minutes as I proceed.

Perhaps farming where we do has prepared us for the drier conditions that have arisen over the past several years. Even on good years our crops and livestock are inevitability stressed at some point in the year by lack of moisture. A very high evaporation rate is part of our problem. To counter this moisture stress we have adopted several practises into our normal farming operation. One of these is subsoiling or ripping. I use a Kello-Bilt 5 shank ripper to loosen the solonetzic hard pan. The first time over the land with the ripper I do the whole field. However usually only about 30-40 percent of the land is hard pan and needs the ripping. Each field is ripped in rotation every 5 or 6 years with only the hard pan areas done on subsequent operations. I only rip to 16" because I find that both the workdown required and the loss of topsoil by deeper ripping is too excessive. The topsoil loss and dilution with undesirable subsoil is a problem. I counter this by dumping chaff, which I save as "free" cow feed, in areas where germination is poor and then add chicken manure. In two years those bad spots are back in production. Another possible remedy to this topsoil problem may be to use the "Para-Plow" but to this point it only is available in 3 point hitch models.

Another way to counter moisture stress is early seeding part of the crop. We start on our sandy land a good two weeks before we can get on the heavier land. This makes the best use of moisture left by snow melt on this light land. Along with early seeding, I also spread my planting out over a longer period if the spring is particularly dry. For example this year I seeded oats and barley as late as June 20 and with the rain in July still harvested 60 bushels per acre of mixed grain.

We have been using an airseeder for six years on a minimum till program. The airseeder allows the flexibility to direct seed or prework if conditions demand. It also speeds up the seeding process to get the seed in the ground at just the right time. Banding fertilizer has also been a plus but we are now banding in the spring to save carrying the cost of the fertilizer over winter.

In 1986 we tried some direct drilling to eliminate tillage. We put 100 acres of flax into wheat stubble in mid-May. The crop got off to a good start with spring moisture, suffered considerably in June and early July, but the good early root development still help to return a 20 bushel yield. Direct drilling has definite possibilities but it will certainly raise, again, the level of management required to handle soil condition, previous crop residues, seeding dates and herbicides.

Spraying with 2,4-D in the fall reduces the need for early spring tillage. This has fit in very nicely with our airseeder and should work well if we decide to direct drill more acres in the future.

I have also been using some clover plowdown to try to build up more fibre in the sandy land. The extra fibre virtually eliminates erosion and increases the moisture holding ability of the soil. The clover crop comes early the second year, makes good use of spring moisture and can be used as an emergency feed supply if required.

Oilseeds have shown me surprising drought resistance. Early seeded canola, if it will germinate, is a very viable option to us. I like flax as well because it is more flexible with spraying and harvest. However when a crop doesn't look promising you must move quickly and reseed. For example this year 50 acres of canola seeded on summerfallow didn't germinate so by the end of June I had reseeded the field to fall rye and had excellent fall pasture for the cattle. Incidently the canola seed on stubble right beside come up just fine. Another reason to "Keep Your Stubble Up".

Even in a "dry" year it usually rains sometime. When it does your land and crop have to be able to take maximum advantage of that moisture. A properly fertilizer crop, with little weed competition on land with good moisture holding ability will utilize as much of that limited moisture as possible. Limit the crop in any one of these areas and you are wasting that precious moisture. I have often argued that lack of moisture was the limiting factor to crop production in our area. Perhaps that should really be proper moisture ulitization is the limiting factor.

After dealing with some of these specific on-farm practices, I would like to turn to some more general topics. Drought is just another one of many problems facing us today. It is really no different than rising costs, falling prices, insects or any of the other negative situations a farmer finds himself in.

The financial position of the farm must be such that periodic downturns can be handled. I don't think this necessarily means a lot of cash in the bank but it does require the sensible use of credit. A few years ago a lot of farms ran pretty close to bone with big debt loads. We all know that the agricultural economy is cyclincal so it was only a matter of time till some people got caught. That more conservative approach also usually allows for expansion when land values drop, the price of machinery comes down, or drought gets another farmer in trouble. If a farmer is confident in his financial position he is much better equipped to deal with problems such as drought, as they arise. Sound financial management is becoming more and more important. Farmers need to learn and hone this skill. Alberta Agriculture is offering their "Gearing Up Financially" program this winter. Every farmer should consider taking the course.

I am also a firm believer in diversification as is self evident from our farming operation. Typically, diversification on a grain farm has meant cattle, and thats fine, cows can harvest short crops much more efficiently than a combine. Also Crop Insurance is now more generous in allowing poor crops to be cut for feed. We usually sell our calves in the fall but this year, to take advantage of poor grain prices and abundant feed supplies, we have put our calves on feed for the fat market next spring. The cash flow from the chickens allows us to keep our calves to offset the low grain prices.

But maybe there are other options for diversification including an off-farm job, or raising red wriggler worms, or maybe mushrooms, or maybe even buying into a chicken farm. When it doesn't rain on the wheat that second source of income looks pretty good.

Any practice that raised the overall productivity and efficiency of a farm makes that farm more able to withstand a problem like drought. New technology and some old technology need only be implemented on any farm to make that farm more secure. A farmer must always be looking for that technology. There are many avenues available such as private industry, extension people with government, farm groups, farm papers etc. I have had the privilege of sitting on the Region II Soils Management Committee, as a farmer member, for the past several years. I always feel that I get more than I give out of every meeting. There are a lot of sharp people with good ideas working with the government and this is just one of the many ways I access their services. The use of 2,4-D in the fall, on our farm, is a direct result of my contact with this committee.

With the budget restraints in the offing there may be a temptation in private industry and government to cut some extension staff. I feel this would very short sighted. Extension personnel are the farmers closest link with new technology. These extension people need to be out in the field, talking the farmers language, and feeling some of joy and pain not locked away in some central location where their only contact with farmer is by telephone. The on-farm demonstration program is just excellent. Farmers can see, at home, what does and doesn't work.

Anything that helps farmers help themselves reduces the need for the expensive "band-aid" programs we seen over the last several years.

At the same time regulations must be enforced. A better system of enforcing the soils act should be in place. Several municipalities are doing a good job but erosion usually has to become severe before much is done. We must make ignoring the conservation ethic more socially unacceptable.

I have rambled for enough so I will come back quickly to my two words "confidence" and "flexibility". To survive a problem like drought a farmer must have confidence in his ability to do everything; every little thing, to grow that bumper crop. His operation must also remain flexible enough to absorb the shock of a crop failure and carry on another year.

We do have a partner in Drought Management. That is Mother Nature. If she doesn't cooperate a little, if it simply doesn't rain, you can manage your head off and you're still going to be in trouble.

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FARMING IN SOUTH WEST SASKATCHEWAN

Les Potter, Producer
Gull Lake, Saskatchewan

I have a 1600 acre farm in the south west corner of Saskatchewan. I was a mixed farm until last fall when I made a decision with the help of my wife and family to dispose of our 75 cow commercial beef herd. We wanted to see what it was like to have some leisure time. That provided to be a false premise. I grew up on the family farm and attended the University of Saskatchewan for two years with the idea of becoming an Ag. Rep. The second year I was lucky enough to get a job with an anthropologist for the University of Saint Louis researching in south west Saskatchewan. The pastures were greener on the other side of the fence so hence no more school. I worked for PFRA in 1961 doing crop yield counts and later spot-checking claims. I then began working for District Ag. Board and in 1964 won the weed eradication award for the mid-western states and three prairie provinces.

In 1965 I married and became a full time farmer. Since then I have been involved on various Ag. Boards. I now am a member of our local Municipal Government for ten years: on District 10 Ag. Board, a member of District 10 Agriculture. Development Fun Committee; Chairman of Southwest Regional Council and sat on the Saskatchewan Advisory Council to Extension Services as well as a member of the Provincial Agriculture Development Fund Board.

I have been a member of the University of Saskatchewan Moisture and Soil Conservation Program previously called farm lab and now the Ag. Development Fund Innovative Acres project.

We were a conventional mixed farm with a two year summerfallow cereal rotation until we started with the new program. After we stated the program we have had some very questionable years. We were hailed out twice, dried out twice and had one average crop and one good crop. But we are still in business so it hasn't been as bad as the picture I have painted.

Through our extended rotation we practice snow trapping and fertilize to wet soil recommendations. The crops grown have been hard wheat, hard wheat, lentils, winter wheat, and winter wheat.

In our Ag. Development fund project we have had excellent cooperation with the scientists from the University of Saskatchewan and the extension staff from the Saskatchewan Department of Agriculture both in planning, decision making and the actual technology used to improve our farms production.

I am one of 40 farms in the Innovative Acres project. I believe that if farming is going to progress at the rate that we would hope it too; that there has to be more money spent on the transfer of technology. We have to have a two-way street between the farmer and the researcher. I believe that this is where we need extension staff to play and active part. We must have contact with the researcher through the extension staff for day-to-day problems. The researcher must have funding available for research in the future and at the same not neglect problems like grasshoppers, and wheat midge, etc.

I believe that as a producer that we can't continue to mine the soil. We must learn that there are other things to farming than how much profit we can net on a given year. We as producers have to be willing to look at alternatives to wheat production. Maybe pulse crops, Lentils, peas, faba beans, etc. ... or maybe forage and coarse grains for our livestock industry on the prairies.

We have to be willing as producers to adapt to change. I feel we have to fertilize to maximum soil test recommendations and use good weed control. This is where I believe producers could put pressure on government to have chemicals developed for Western Canada at a price the crop yields can afford. For example chemicals and fertilizer costs should not exceed 20% of average production gross returns. Government must tie returns to input costs.

Here I would like to suggest some ways that Provincial and Federal governments could change the rules and improve farming.

I would suggest the first that should be changed is crop insurance. I believe that if crop insurance was run on an individual yield basis it would provide an incentive for the producer to become an innovator; if he were able to protect his high production costs. Instead of the present 80% production the producer should have the option of choosing 50-60-70 or 80% production levels.

I I feel that the cattleman should also be able to buy grazing land production insurance on native as well as tame grasses. The livestock producers should be able to buy forage insurance to cover such forages as Rye and oats, etc. This type of insurance would encourage good range management (fertilizer weed and brush control) as well as urge proper land utilization. Good land for forages and pasture land for grazing. A proposal for rang land insurance would be far cheaper than the forage and livestock subsidies in the past.

I think that if reasonable grazing insurance could be obtained it would be more economical for acres of Class 5 and 6 land to be in livestock than grain. Grazing yields don't vary to the extent the grain yields do on these lands.

I would like to suggest that maybe the next government rule that could be changed would be the system of quota acres.

I believe that one of the ways of managing moisture and soil conservation is extended rotations. It is a proven fact that summerfallow is costing those of us that live in this semi-arid climate a lot of money. If a person was allowed to deliver more grain on seeded stubble producers (knowing the technology , i.e., fertilizing, spraying, snow management) would have some incentive for the increased input costs. At present unless you have no summerfallow the innovative producer is penalized for seeding stubble. Farmers in my area still feel that some summerfallow is required (believing it is an insurance after a dry year). I am wondering if this is false economy. We must have an incentive to seed stubble. Soil conservation doesn't seem to be enough.

Maybe this is enough of my ideas on how to solve the nation's agricultural problems.

In my own case I started in 1965 and went through the dry years of 67-68 and poor markets in 69-71. In 1972 I lost two of my advisors on the family farm, my Father and Grandfather. HELP..there went some 65 years of experience. Shortly after this we began to expand both in land and cattle numbers. After my first encounter with farm credit and finding out that they were suggesting debt repayment with six dollar wheat. This is contrary to what my roots had drilled into me; that farming was a series of highs and lows. I began to try to intensify my farming operation. I believed that every acre on our farm must return something to our operation; be it livestock feed, land rental, or grain. We found that barley responded well to fertilizer and it seemed to mature ahead of our extreme heat in August. Thus our first stage in extended rotation.

By 1979 we were growing about 20% of our wheat average as well on stubble.

This is when we started to gamble. On the following years we began to soil test 50% of our fields a year some stubble and summerfallow.

Because my land is a silty-clay loam in the brown soil zone we were having problems with wind erosion. We bough hoe drills with narrow openers for a minimum soil disturbance and have progress to minimum tillage and spraying on summerfallow and spraying in fall for weed control of winter annuals and direct seeding on stubble.

We found that the first two years of this type of operation were very trying.

Our first year of using extended chemical fallow was a disaster; we had 12 inches of rain to our normal 6 in the growing season and our chemical fallow bill reached $30 per acre by mid July. Out we went with the cultivator.

Our fertilizer input remained fairly constant around $17 an acre; since then our yields have stabilized and our inputs for chemical fallow are around $11 an acre.

I believe that the roughest point of this farm plan is in the family decision making. I have three children going to University at different times and we haven't had a family holiday in seven years. My family is very good about not letting our farming operation deteriorate. Fertilizers and sprays come before cars for my kids or new living room furniture.

We have found that with the tight economy we have become very close on farm decision making. My wife and my sons provide the additional farm labour we require. Previous to the down turn in the economy we had some outside help in the summertime. Then holidays were possible.

I feel that one of the most important things in going into a rotation program is that it is a total family commitment for a minimum of five years. Returns start to show up significantly on the fourth year. You must have the financial resources to carry the program through. If it is dropped in the first years you lose all that you are striving for as well as high inputs reap very low benefits.

In my case in 85 we had two inches of rain in the growing season and we combined a crop; not a good one mind you; but we combined when some of the neighbours didn't.

In 86 our chemical fallow suffered. We were forced to blacken summerfallow for grasshopper control. Back to the drawing board I guess.

In summary, drought proofing measures that have worked on my farm:

1. Snow trapping.
2. Minimum tillage and chemical fallow.
3. Extended rotation.
4. Direct seeding in the spring and using chemical for weed control.

The suggestions for the government and the industry:

1. Crop insurance changes.
2. Livestock on Class 5 and 6 land.
3. Quota acres changes.
4. Funding for researcher to spend more time exchanging ideas with farmers.

A MANITOBA PRODUCER'S EXPERIENCE IN DROUGHT MANAGEMENT: A VIEW TO THE FUTURE

by: James G. Nielsen[1]

Drought···too little rain, too much heat, too many dry winds···is the major climatic limitation to production on our continuous crop wheat and oilseed farm in South Western Manitoba. Drought is a major factor which must be considered in the farm management decision making process.

The farm is located four miles from the U. S. A. boundary and thirty miles from the Saskatchewan boundary in the Thin Black Soil Zone, the transition zone between the Dark Brown Soils of Eastern Saskatchewan and the more northerly true Black Soils with a deeper A horizon. Over the past twenty years the introduction of improved technologies such as larger and more modern machinery, selective weed control chemicals and increased use of NPKS fertilizers has converted this "1930 dust bowl" from a land where 1/3 to 1/2 of the area was summerfallowed, to an area where successful continuous cropping practices prevail. Farmers in the area are prepared to accept the risk of drought to eliminate the possibility of wind erosion on summerfallow. The adopted continuous cropping system which utilizes minimum tillage has been very beneficial both from a farmer and soil conservation point of view. This system combined with increased fertilizer use has resulted in a buildup of soil nitrogen and phosphorus. The more fertile soils and timely operations has provided for more efficient utilization of limited soil moisture supplies and therefore yields have increased.

We cope with the potential for drought by placing this yield limiting factor in its proper prospective. To determine what will happen on our 1700 acre farm the following parameters would be considered.

1. all acres must be planted
2. there must be an absence of weeds to allow the crop to utilize all available moisture
3. fertilizer inputs must be optimized in relation to the response curve for our area to assure the benefits of years of adequate rainfall and nutrient carryover is expected in drought years
4. machinery must be adequate to allow for timely operations which reduce water loss
5. crops must be chosen in relation to their drought resistance··· wheat acreage is maximized, sunflowers may be selected over canola, winter wheat may be chosen over barley
6. crop insurance must cover operating costs.

We have one rule···the day we can not afford weed control or fertilizer··· it is time to sell out.

Continuous cropping practices necessitate higher capital investment, greater input costs and considerably more management skills. The system works well when it rains, however, when drought occurs, especially for more than one year, it will take its toll on those farmers who do not maximize production under the drought circumstance; a number of my neighbours are no longer farming for this reason. Drought has to be a factor in the farm management decision making process i.e. it affects crop selection, weed control practices, the amount of fertilizer applied, the number of tillage operations and more. Drought not only plays a major role in the business of farming but also has major implications for the whole rural environment. Only someone who has watched his/her crop dry up and burn up, can appreciate the real stress which drought can place on an individual, the family, and the community.

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[1] Farmer and Agricultural Consultant, Box 141, Goodlands, Manitoba, Canada, ROM ORO, (204)658-3427, October 15, 1986.

On our farm we continually search for crops which are more drought resistant but the crop must also have adequate disease resistance to withstand the wetter years. Our safflowers produced well for two dry years, however in the third year it rained and the crop was destroyed by disease. Similarly the future of winter wheat, as an excellent early maturing crop in a drought area, was quite promising until the rust infestation this year. Possibly new cropping practices such as tram lines and the speculative use of fungicides is the answer, however when the risk of drought, combined with today's economic environment is assessed, the practicality of this system must be questioned. Hard Red Spring Wheat is still the best drought crop possessing the ability to produce under all conditions. For the future of our farm, research on drought and disease resistant crops is placed very high on the priority scale, as is the need to look at the real future of farming in droughty areas. With declining crop prices, more and more of the droughty areas will simply be forced out of production. In the context of world production, can we compete with areas where it rains···120 bus/ac wheat produced in Europe, 8 t/ha of palm oil from Asia. Does this illustrious group have the answer? We, the farmers, look to you to analyze, understand and shape the future. Do you get together often enough to contemplate the future so the work you do will produce the greatest long term benefits? At today's grain prices, it is doubtful if there is any future farming droughty areas, so we need all of your expertice and wisdom in this time of crisis. As farmers, we must become more efficient if we are to survive, there is no margin for error remaining.

The terms "conservation farming practices" and "soil degradation" are common place in today's agricultural society. I gave up going to church on a Soil Conservation Sunday because I could not tolerate someone preaching about how we are destroying the soils in our area. The adoption of continuous cropping has virtually eliminated wind erosion, and, water erosion has been reduced significantly; our soils have never been looked after in a better fashion since farming began in the area. Continuous cropping is the first and foremost conservation farming practice especially when it is combined with minimum or zero tillage. The development of more drought resistant crops would help our area and may make continuous cropping practical in even drier areas.

The "word" in Manitoba is the "ICM" System or the Integrated Crop Management System. It is an approach to management which should be discussed in relation to drought. Why not recognize the problems, and with a positive attitude, begin developing "Integrated Drought Farming Systems". Present technology could be assessed, objectives created and programs priorized to fulfill the purpose of developing farming systems for different degrees of drought throughout the Prairie Provinces. It would be a way to coordinate research and development. Our information supply is limited at this time. There are so many questions to be answered which will affect the future of farms in relation to surviving drought···minimum tillage or zero tillage; how should fertilizer be placed; which of the 30 or is it 100 different machines would do the best job on the farm? Other questions need to be answered. Does fertilizer pay under drought conditions? What degree of weed control should be attained? Should stubble be left standing to trap snow? There is no coordinated approach to drought farming. Rather than individuals working on individual items, developing and promoting feasible drought farming systems would be a step forward. Federal, Provincial and Municipal Governments have a major role to play in drought management by providing the long and short run focus on practical research.

The agricultural professionals working in government and industry are quite competent, they do their job and useful information is available, however, budgets are simply inadequate, therefore, services are not keeping pace with changing technology. Proper funding of innovative research, demonstration and testing is necessary if western Canadian agriculture is to remain efficient and competitive in world agriculture. An overall policy toward the continued development of farming systems which will more adequately cope with drought would be both profitable for the farmer and would achieve many of the conservation goals which are receiving priority in today's agricultural environment. To be more specific, an integrated effort to continuously develop improved drought cropping systems must be a priority of government and could be financed by utilizing a portion of the funds spent on ad hoc drought relief programs in western Canada over the years.

MOISTURE MANAGEMENT IN CROP PRODUCTION CONFERENCE

SUMMARY/CONCLUSIONS/RECOMMENDATIONS

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MOISTURE MANAGEMENT IN CROP PRODUCTION - 1986

Mr. Chairman, I would like to take this opportunity to thank you and the organizers for the invitation to be here. It is rather overwhelming to me - this is the second conference of this type that I've summarized and I find every time it happens that I learn an awful lot more than I ever expected I would.

As you know, I'm not a professional agriculturalist. I'm a professional manager, and given that perspective I trust you will be tolerant because I do not pretend to know agricultural issues as deeply as many of you do. I'm also an urban person. I was born and raised in Edmonton and I have come to learn a great deal in the last few years about the importance of our rural economy. Consequently, my comments will be influenced by my past and what I have learned in the past few years.

My job is to synthesize and report, to summarize, conclude and recommend, and I think that is likely a bit of an overstatement of what I'm able to do in the couple of hours I was upstairs in my room this morning. What I did do was listen to most of the presenters. I read all of their papers. I maintained thorough notes and I went back to my room and I reviewed those notes before I put my comments together today.

I would make one immediate recommendation to all of you and that would be to read the proceedings when they come out. There is more in the speeches than what the speakers were able to present, and I certainly commend that documentation to you.

Let's move along then and define what I consider to be the issue, and this is the old trick that the student plays of redefining the exam question and then answering the redefinition. Sometimes you can get away with it. I trust you'll be kind to me in that regard.

Is the question we face really moisture management? Don Getty in his address in the Conference brochure said, "the last four conferences have served as forums for the exchange of agricultural research information and management practices pertaining to our soil and water resources". I am assuming that John Girt made it through most of his paper today and had the opportunity to identify his concern that, since the water holding capacity of soil can be reduced by soil degredation, he had to choose to regard soil conservation as an integral part of moisture management. In effect, it seems to me that the question of continuing agricultural productivity, soil conservation and moisture management are intertwined. One challenge cannot be considered to the exclusion of the other. Conservation must have a payoff for the farmer. I'm going to interchange those words in the next few moments, but remember that they are part of an inter-related whole.

Deeply Embedded

I'd like to take just a few moments and provide some context for the issues that relate to agriculture and conservation. We all know that those issues are deeply embedded in our economy. We know that agriculture represents about 4% of our labor force, it employs one of five working Canadians, and accounts for one-sixth of Canada's economic activity. The real problem is that this 4% is almost invisible. Conservation is such an intimate part of agricultural production that its effects become deeply worked into our economy and it tends to become invisible. It takes many, many years to see the results of poor soil and water conservation practices. We all need to be far more aware of these long-term and cumulative affects.

Exceedingly Complex

As well, the issues we are talking about are exceedingly complex. Agriculture itself is a very complex business. It involves every single piece of information management and current technology that one will see in a major corporation. The farmer usually manages the situation with two or three people - not with an office of corporate research and planning, and not with an office of marketing. I think in that regard we really need to give recognition to our departments of agriculture, our research scientists represented here today, our universities and a host of people in the private sector that service agriculture.

Additionally complicating are the range of time spans faced by producers. The time horizons of conservation must be long, but the farmer is faced with the immediate need for survival. Adding more complexity are the many forms of soil degredation and moisture management and their many inter-related solutions. I think that point has been amply made over the last few days. Conservation is not to be effected through the use of a simple recipe, or only national and provincial policies. Solutions have to be enabled by wise policies, but in the long run the solutions must be local. Given the range of information necessary for soil conservation, the wide levels of participation, and the long time horizons, we can appreciate that soil conservation, moisture management and agricultural productivity are extremely complex issues.

Technologically Sensitive and Information Saturated

As well, conservation and agricultural productivity are technologically sensitive and are information saturated. Some people have suggested today in farming that the issue is management of capital. Even recognizing that as an over-simplification, we all know that to manage we need a wide, wide range of information. Individual farmers know about establishing values and decision-making, control and application of choices between alternate ways of allocating resources as critical issues which face them today in an effort to maintain agricultural productivity and appropriate conservation practices.

It is clear, also, that conservation and appropriate levels of agricultural productivity demand tremendously varied sources of information.

For example, producers today must deal with issues associated with land types, cropping rotation, fertilizers, herbicides, machinery applications, economic analysis, research trials of your own, current scientific research, market information, hedging, policy involvement, and on and on it goes.

Just for the fun of it I wrote down a partial list of new terms that I heard in the last couple of days: chemical fallow, partial fallow, eigon vectors, relation of moisture conservation and precipitation, envirotranspiration, soil types, jet streams, zero till, snow harvest, deflectors, variable fertilizer rates, slope positions, weather patterns, moisture use effectiveness, grasshoppers. Need I go on to make the point?

Without that flow of information and technology from the minds of researchers into the hands of the practising farmer, the challenge of agricultural productivity and conservation is lost. That flow must not be impeded at any point along the way.

In terms of the amount of money spent in Canada on conservation, it is interesting to note the following facts. I have to thank Gary Fairbairn for his observations in "Will the Bounty End". He observes that the Canadian government's spending on conservation often lags far behind the United States, even though many observers consider U.S. levels to be inadequate. One study found that federal government expenditures on soil and water conservation in Montana totalled 3.4 cents for every dollar of farm production. Similar federal expenditures on the Canadian prairie, meanwhile, were only 2/10 of a cent. Even allowing for Canadian provinces having a greater role in conservation than U.S. states, there is still a large discrepancy. In 1983, Canada's total activity in soil conservation, degradation and reclamation research was only 32 person-years. In effect, all the professionals doing basic research could fit into a small school bus. What a commentary on the provision of information! Thus, conservation is not only extremely sensitive to the provision of new technological information, but it is also extremely sensitive to the ongoing generation of up-to-date research and information.

Information Management

The problem that faces us is one of information management. John Calpas at the outset said that, "we are drowning in information yet grasping for knowledge". I wrestled over the last two days with how to deal with that issue. It appears to me that the first things we have to do is to decide what matters. We have to identify values. We have to clarify goals and build priorities. Then we have to act on those priorities and evaluate our actions. I'll say more about values in just a few moments.

It appears to me that the whole question of information management is also related to the people who are going to use the information. I regret not having heard Henry last night, but I have worked with Henry before and I think I know the message that he was sending. I know he was concerned about producer involvement. If we are talking about information management - getting it to where it counts - is the bottom line. Getting it to the producer. Don Getty said in his comments as well that "widespread use of conservation farming practices will not occur until farmers are convinced of the practical and economic advantages of applying the technical information to their own operations."

John Girt also said in his paper that the lack of sufficiently organized dialogue is critical. There needs to be more producer involvement and emphasis on programs specific to farmers needs. I think these points are relevant to the question of information management.

I do not want to be unfair with anybody here on my next point. I have a great deal of respect for the people who presented papers. I am personally subject to the criticism I am going to make and I know the nature of the problem. We need to clarify the language that we use and make it appropriate to our audiences. Science speaks of the world in words that are different from the way other people speak. Science talks about probability, statistical levels of confidence, paradigms and models. Producers speak a different language. They talk about risk, chance and survival. An effective technological transfer of information management calls for a better bridging of these perspectives.

Another important conservation point made by Elmer earlier in his comments, had to do with making your definitions clear. What are we talking about when we talk about zero till? It is important to be clear that what you are sending is the same thing for the receiver of the message. Clear definition is important.

The technology transfer chain must be complete and clear communication is central to completing the chain. Strategies must exist and be supported at every level from basic research to commercial applications. I will make some recommendations and observations about that just a little later on.

Finally, I would like to draw your attention to one other conceptual point with which I think we are all familiar. We have already observed that solutions to conservation must be fostered by wise policies, but the actual application must be uniquely local in nature. In addition to this need, we face the real problem that soil and water do not know political boundaries. Agricultural production and conservation are two of the greatest challenges to face the Canadian federal system. We require a concerted effort to pursue long-term strategies that require understanding and cooperation from a host of federal, provincial and municipal agencies, not to mention the political parties at all levels, consumer groups, environmentalists and the producers. In short, the problems facing agricultural conservation must not be left to a comparatively small group of people. Our nation and province must recognize the growing problems and make a rational commitment to solving them. Like a French statesman said once long ago "you can't leave war to the Generals". Conservation can't be left to small groups of people either. Conservation is a social issue and we have to recognize that and all be involved.

Values - The Ultimate Issue

These points lead me to what I think is the ultimate issue that we face, and it is an issue of values. The central issue of conservation is one of social value and ethic, both of which must ultimately come together to produce the political will necessary to effect solutions. While I have indentified that conservation must be viewed in a long-term perspective, does our society provide farmers with the ability to behave on a long-term basis? Do we see soil and water as commodities to be used, or do we view them as resources to be conserved? Do we have a conservation or a consumption ethic in our society? These are fundamental issues which society must decide. Failure to do so whipsaws the producer and inevitably results in conservation being impossible to practice.

Theodore Schultz, the 1979 Nobel Prize winner for economics, made some observations in his Nobel lecture. His address entitled "The Economics of Being Poor" made the point that society's investment in the knowledge and skill base of its producers must not be viewed as consumption expenditures. He argued an extremely cogent case that such investments have a very material effect in changing the quality and quantity of life in countries where investment in the skill and knowledge of the agricultural human resource has been carefully practiced. John Girt made that point in his paper as well.

Let me paraphrase a couple of other points made by Dr. Schultz. Since learning, new knowledge and education, however acquired, is primarily an investment, it is a serious error to treat these costs as current consumption. This error arises from the belief that learning and the provision of information is solely a consumer good. It is misleading to treat such public expenditures on information provision and research as "welfare" expenditures, and as a use of resources which has the effect of reducing savings in the country. Precisely, the reverse is the case. Such expenditures are investments. Analysis of such investments in the agricultural sciences, for example, provides clear evidence that the rate of return can be approximately 40%. This is indeed high when compared to the returns for most other investments designed to increase agricultural production.

We talked a little bit at the beginning of our Conference about assumptions, and I do want to thank Tim Ball, although I suspect he's not here, for a point that he made when he emphasized the need to check our assumptions. We need to question them. Some of the examples that I extracted over the last couple of days were assumptions like the following:

Climate can't change. We know it can. Droughts and floods don't affect us! Economies are always stable. This is not true. Life is a straight line. We know it is not; it is curved. Snow is a pain. No it is not. We have learned it is a resource. Highways detract from production. No, they can add if ditches are used properly. Those are just examples of how we need to be careful to check constantly our assumptions about what's going on around us.

I suppose the lesson here is also straight forward. Change is the constant. Thus if we are constantly reviewing our assumptions, trying to respond to change, what are the best strategies to use? Is it inflexibility or is it flexibility? Is it monoculture or diversity?

If we admit to these considerations, what are the implications? We know that all our actions are based on values. It doesn't matter what we do, there is a value beneath each decision. We need to be conscious of these values and to decide if they are acceptable in the general society. Values must not just be buried in action. We need leadership which flows from a clearly identified base of values. Burying our values in action is what gets us off-track so many times, because if we do not consciously know what our values are we have difficulty setting our priorities. We need government by principle not by opinion polls.

So let me make my earlier point again. We need a shift in attitude and values which sees investments in conservation, information and technology as just that - investments and not consumption expenditures. Failure to maintain such support for agricultural productivity and conservation will reap an awful harvest in decades to come. On the other hand, appropriate investments in research and technology transfer will reap a very rich harvest in the future.

Final Observations

Now let me proceed to the last portion of my paper, some observations that we might consider to be conclusions. You all know the uncomfortable fact that much of our political process today is influenced by urban voters, and I think Derek referenced it this morning. You will recall that agricultural producers represent about 4% of our labor force. Consequently, those of you directly concerned with the effects of conservation are a minority in our country. This suggests very clearly that we need to organize ourselves to influence and develop policies which support conservation and agricultural productivity. Let me, through a series of need statements, highlight some of the courses of action which I believe must be taken. I present them in no particular priority, but simply present them for your consideration.

Policy Organization

- We need to inform the general urban consumer/voter about the challenge facing agricultural productivity and conservation today.

- We need to begin this process of informing at an earlier age for all of us. Some have suggested the compulsory integration of water, soil and air issues in school curriculum. It is necessary to focus attitudes and awareness with urban and rural students.

- We need policies to direct urban and industrial sprawl to non-productive land or where use of productive agricultural land is absolutely unavoidable, then compensation must be provided.

- We need policies to preserve and enhance productive agricultural land.

- We need policies to provide incentives for the support of conservation.

- We need either to create or use an existing body to speak for and coordinate conservation in our provinces and in our country. To this end it would be useful to coordinate and clarify relations between such organizations that we've heard about: agricultural service boards, conservation districts, municipal districts, and local research organizations as they relate to conservation practice.

- We need the costs/benefits of conservation to be viewed in a wider social context than just the cost benefits to agriculture.

- We need a revision to Wheat Board quota systems so that they will encourage soil conservation practices.

- Again, we need hail and crop insurance programs to be revised and methods proposed by which soil conservation can be encouraged through the policies of insurance plans.

- We need to encourage widespread adoption of effective practice through incentives which reward successful management.

- We need to build continuing awareness of successful programs across Canada and around the world.

Obviously, I could carry on and I apologize to those of you whose papers didn't get a "we need" statement out of them, but I did my best to identify the highlights. I hope I have made the point that certain levels of organization for the purposes of developing and influencing policy are a must. One would like to argue that we need a national conservation service similar to that which exists in the United States. However, given the political realities of our federal system and the responsibilities of provinces, we must initially argue for a soil and water conservation focus to be provided for by the provinces. We could only hope that intergovernmental discussions would provide for coordination of such inititives on the federal level as well.

In spite of the need for action at these higher levels in our society, we must not lose sight of the fact that the real action must start at home where the operational problems exist. Soil and water conservation groups must spring up to influence the development of policies at the provincial and national level. Such bodies may need to be created anew; however, I know we have existing organizations which, with simple adjustments in their mandates, could undertake soil and water conservation responsibilities. It is so important to observe that our current fiscal environment is going to require us to do more with the same amount of money. We cannot create new organizations. Existing ones are going to have to be modified and redirected to solve some of these problems.

Technology Transfer

Now, let me point to a last set of observations in relation to the creation of effective technology transfer mechanisms. First of all, demonstration, and let me use the same format I used earlier - a series of "need" statements.

Demonstration

- We need to demonstrate for farmers the value of cost-effective conservation practice.

- We need to view the research chain as composed of the following components: research, applied research, demonstration/field trials and commercially viable implementation. A merging of all steps in this chain must be forged to provide for extensive demonstration of successful application alternatives and I think there is evidence of those kinds of relationships emerging across our country. They need more support, and I know in our province Farming for the Future is a very clear and positive example. I know there are other examples in the West.

- We need to organize forms of soil and water conservation districts to foster these demonstration/field scale applications.

- We need to provide for the involvement of other private and nonprofit organizations such as Ducks Unlimited in on-farm demonstrations of commercially viable conservation practices.

Acceleration of Technology

We know, as I said earlier, that conservation practice is highly sensitive to current technology and information. We also know that such information can be available but not accessible by individuals who need it. Jim made that point at the end of his comments this afternoon. Such conditions inevitably lead to very slow adaptation of new and improved techniques.

- We need to engage in activities to accelerate the transfer of technology which bears directly on increased agricultural productivity and conservation. Let me say it again - We need to engage in activities to accelerate the transfer of technology which bears directly on increased agricultural productivity and conservation. I think John Girt made the comment in his paper that this is where the focus of research needs to be. It needs to be less on the development of new technology. I am not here to argue the relative balance needed. I want only to stress that a balance is needed but a present emphasis on application of technology to conservation and production is critical.

  Fostering these kinds of local demonstration and field trials is one way of accelerating the transfer of technology.

- We need incentives and funding assistance to facilitate producers' assessment of ways to transition into conservation practice and yet continue to survive.

- Consistent with successful practice elsewhere, we need to make available to producers, on a rental basis, conservation equipment in order that the new equipment and techniques can be evaluated thus assisting transition to cost-effective conservation practice.

  Such an approach should encourage participation of private sector implement dealers, and should include the use of a professional advisor with the equipment to take advantage of existing municipal organizations to do this activity.

Training and Education

While we have talked about the need to integrate air, water and soil into curricula, that focus has primarily been one of awareness for students in the basic school system. We have not dealt with the fact that there is no totally integrated program in western Canada to train technologists in the areas associated with soil and water conservation.

Much of what I have been observing calls for access to trained manpower. It would seem that training at the two-year technologists level would make a considerable amount of sense. These individuals can be trained rapidly, and in the event of shifting market demands can be retrained with a minimum of expenditure and dislocation for the individual. Furthermore, such technologists can work in an efficient relationship to fully trained soil or water professionals. Such a professional can manage a number of technologists and ensure that a larger volume of services will be provided to the producer.

- We need to assist in defining new and/or existing policies and educational program proposals which support the development of trained manpower in the areas of soil and water management.
- We need to continue pressure on government, and provide encouragement to universities to ensure the training of adequate numbers of soil and water profesionals. The numbers are declining and it would be terrible to wake up to that fact in five or ten years because it takes a good portion of that time to train researchers.
- We need to continue pressure on government and private sector research agencies to establish a focus on soil, water and conservation management technology. Without this basic knowledge input the whole process of education and technology transfer begins to die.

Conclusion

Let me conclude. In the last few days I have heard a number of words that keep running through my mind. I have heard harmony, balance, equilibrium, (that's a scientific word for balance), interdependence, integration, cooperation, and diversity. Obviously all of those words say something about how we work to deal with the challenge facing us. It is not beyond our ability, in my opinion, to influence and manage that challenge. We need to work together to create organization structures and develop processes which will allow us to influence the policies that need to be created. There is no choice but to become active in this area. We do, in my opinion, need an organizational structure across our provinces and in Canada to provide a very specific focus on the question of soil and water management and conservation practices.

There is a licence plate that's been driving around Calgary that says "Lord, please give me another oil boom - I promise not to blow it all away this time". You know we are likely not going to get that kind of chance again. I am 44 years of age and I have not been through the depression, but I am concerned we will not see a boom like that in our lifetimes. It means we have to establish measured and thoughtful ways of dealing with the problems which we face. And all of that, of course, is of no avail if we fail to organize ourselves in areas of transferring that technology to the specific farm level. I've already reviewed some of those points.

I don't know any producer who practices soil and water abuse on purpose. Given the choice to conserve or to survive we obviously choose survival now. But society, and that means us, must not require nor allow such a choice to be made. Conservation and survival are dependent on each other. Conservation is a long-term process. At one level it is a value and an ethic. At the other level it is today's practice. Producers must not be forced to set one off against the other. It is clear that they don't have to make this trade off. Knowledge is available. This Conference witnesses this fact; however, society must clearly identify and support conservation as a preeminent value for us to pursue.

We leave the future with two things: the environment; the soil, the water, the air, our natural resources. If you are thinking of the heritage we pass on, one of the things you leave is the environment. The other heritage we leave is our children; the people, the human resource. I guess the question for us is how will we leave these legacies. Will they be consumed and empty, or enriched and full? Will they be exploiters or builders; consumers or stewards? There is really no choice. The real choice is to act now in the direction we know is required.

Thank you very much Mr. Chairman. I have appreciated the opportunity.

November/86

MOISTURE MANAGEMENT IN CROP PRODUCTION CONFERENCE

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